PLANT LIFE AND ITS ROMANCE

F. E. WEISS

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BY

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WITH ILLUSTRATIONS

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PREFACE

THE contents of this little book formed the subject-matter of twelve broadcast talks to school children. The object of the course was to evoke an interest in the various kinds of plants which make up the vegetable kingdom and to explain the processes by which the past and present floras of the British Isles have been gradually brought about. The successive chapters deal with the romantic progress of vegetation in the course of its evolution from the minutest of primitive plants to the gigantic conifers of California and the sturdy British oaks. During this rise from the simple ancestors of the past to the elaborate Flowering Plants of to-day, the descendants of the primitive aquatic plants have gradually adapted themselves to a land habit, constantly occupying more territory until they have covered all the habitable portions of the earth. This triumphant progress may well be termed the romance of plant life, and with a view of keeping this fact steadily before the reader, stress is laid in each chapter on the evolutionary point of view. It is not possible, however, to deal adequately with the process of evolution of the higher plants as a whole until some knowledge has been gained of the various groups of plants

which constitute the vegetable kingdom, so that the theory of evolution is dealt with in a more connected form towards the close of the book.

The geographical distribution of plants and the gradual building up of the British Flora of to-day from its various sources is a subject too frequently omitted from botanical books, and yet one which is full of interest.

In dealing with so vast a subject in so small a compass, it is obvious that many important aspects have to be passed over, and the author can only hope that some of his readers may have their appetite whetted for further study of plants in some more comprehensive textbook of Botany.

CONTENTS

CHAP.		PAGE
I.	The most Primitive Plants	1
II.	Seaweeds	11
III.	Mushrooms, Toadstools, and Moulds	20
IV.	Bacteria, the most Minute Plants	33
V.	Liverworts and Mosses	44
VI.	Ferns and their Life-history	56
VII.	Horsetails and Club-mosses	67
VIII.	Conifers and their Allies	79
IX.	Flowering Plants and their Origin	90
X.	The Evolution of Plants	102
XI.	What the Distribution of Plants teaches us	113
XII.	The History of the British Flora	124
	Index	134

LIST OF ILLUSTRATIONS

FIG.		PAGE
1.	*a*, Euglena; *b*, Chlamydomonas; *c*, Pleurococcus; *d*, Diatom, side view and front view .	4
2.	*a*, Frond of the Bladder-wrack; *b*, Portion of a Sterile Frond of the Sargasso Weed . .	15
3.	Diagrammatic Drawings of a Mushroom . .	22
4.	Magnified Representation of the Spore-producing Filaments of the Blue Mould (*Penicillium*)	28
5.	Magnified Drawing of the Fructification of the Pin Mould (*Mucor*)	29
6.	*a*, Various Forms of Bacterial Cells; *b*, Root of a Plant belonging to the Pea Family . .	36
7.	Yeast-cells	40
8.	*a*, Thallus or Frond of a Simple Liverwort; *b*, Two Moss Plants bearing Rhizoids at the Base of their Stems and Pendulous Spore-cases on a Stalk arising from the Top of the Leafy Stems	45
9.	*a*, Pinnule of the Frond of the Shield Fern; *b*, Section taken through a Sorus; *c*, Enlarged View of Spore-case	60
10.	*a*, Prothallus of Fern; *b*, An Older Prothallus .	63
11.	*a*, A Fruiting Stem of a Horsetail; *b*, Terminal Portion of a Shoot of the Stagshorn Moss .	71
12.	*a*, Closed Cone of Scots Pine; *b*, Dwarf Shoot of Scots Pine; *c*, A Cone Scale of the Pine; *d*, A Fruiting Branch of the Yew . . .	81
13.	A, Diagrammatic Section through a Typical Flower showing the Arrangement of its various Parts; B, Capsule or Seed-vessel of the Poppy	92

PLANT LIFE AND ITS ROMANCE

CHAPTER I

THE MOST PRIMITIVE PLANTS

THE vegetable kingdom is made up of a great variety of organisms ranging from minute forms which can only be seen with the aid of a microscope to those giant trees of California which grow to a height of three hundred feet and more. Yet in spite of these great differences in size and structure they have all certain characters in common, which cause them to be grouped together as plants and to be placed in what we call the vegetable kingdom. Plants share also with animals certain characters such as the power of growth and reproduction which are common features of all living organisms. Indeed, when we come to examine the most primitive forms of life it is not always easy to determine whether they are primitive plants or animals. One of these primitive organisms is the microscopic form called Euglena, one of which is very greatly enlarged in fig. 1, *a*. It is only about one five-hundredth of an inch in

length, but occurring in millions together it often causes the pools of water in which it is found to appear quite green in colour, for it possesses the green colour so characteristic of all vegetation.

Ponds and ditches are often coloured green by little floating plants, the duckweed, which may cover the surface of the water, but Euglena is quite microscopic and cannot be seen with the naked eye. It lives in the water, sometimes below the surface, sometimes coming nearer the surface. It is most frequently seen in spring. As early as February, pools containing stagnant water, particularly if there is some decaying organic matter in them, appear covered with a thick green scum. If the weather gets very cold this disappears, the Euglena sinking to the bottom for a time to come up again when the temperature rises and particularly when the day is bright. As the summer approaches these microorganisms disappear, going down into the mud, in which they bury themselves, and if the pond should dry up they will be found in a resting condition in the dry mud, to be revived again by the autumn rains. Euglena has a somewhat oval or pear-shaped body, and its outline is changeable as it has no rigid wall around the living substance, which we call protoplasm. It owes its green colour to a star-shaped group of green bodies, which are shaded in the drawing, and which contain the green colouring matter or chlorophyll that is characteristic of most plants. It is the same colouring matter which makes the

grass and the leaves of the trees green and which we generally associate with plants. Except for its green colour, Euglena resembles very closely the most primitive types of animal life, the so-called Protozoa. It has been suggested that these simple forms of life which link up the animal and vegetable kingdom may resemble the first living organisms from which probably both plants and animals have descended. Like some of the simplest animal organisms, Euglena can swim about in the water by the rapid beating movement of a long, slender thread or filament which is called a flagellum (or lash) and which you can see inserted in a hollow at one end of the body. If you watch a live Euglena in water under the microscope you might think that its movement was quite aimless. It twists and turns about apparently without cause. Yet though it is of so simple a structure and possesses no special nervous mechanism, its movement is not entirely purposeless. Near the insertion of the flagellum is a little mass of bright red colour, which I have indicated in the drawing as a dark body. This is the so-called eye-spot, that name indicating that it can perceive or is sensitive to light. If you place some water containing Euglena in a saucer you will find, if you put it a little distance from the window, that these minute organisms will collect at the window-side of the saucer, and if there are a sufficient number they will make a green line at the water edge. They are evidently attracted by the light, which is of great

importance to them, as like other green organisms it is only in the presence of light that the green colour enables the plants to build up the organic material upon which they depend for their nutrition. On the other hand, it is remarkable that if the light is too intense they swim away into a shady spot. In nature

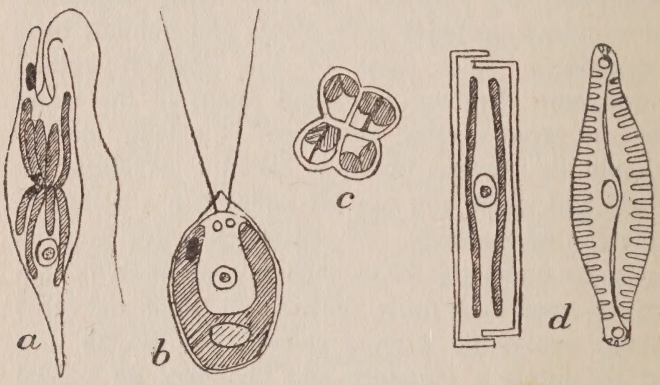

FIG. 1.—*a*, Euglena; *b*, Chlamydomonas; *c*, Pleurococcus; *d*, Diatom, side view and front view. All are greatly enlarged. The chlorophyll-containing bodies are shaded.

it has been found that at night the movement of Euglena ceases—it rounds itself off and sinks down to the surface of the mud, to rise again as soon as the light stimulates the flagellum to begin its beating movement.

Similar to Euglena, and often found with it in the same ponds, is a more spherical little organism called Chlamydomonas (see fig. 1, *b*), which differs from Euglena in being surrounded by a delicate membrane,

so that it always keeps its round form. It possesses two vibratile threads or cilia, which are its organs of locomotion. The green colouring matter forms a cup-shaped body (shaded in the drawing) in the hollow of which is the so-called nucleus, the directing centre of the organism. Chlamydomonas, too, possesses an eye-spot (black in the figure), which, like that of Euglena, is sensitive to light and directs the movements of this microscopic plant. If you cover a little bottle or tube containing water with Chlamydomonas in it with brown paper, leaving a little hole for the light to penetrate, you will find when you remove the covering, after an hour or so, that the Chlamydomonas has formed a green patch at the point at which the light penetrated. At certain periods and under certain conditions Chlamydomonas loses its cilia and the organism passes into a motionless condition representing a resting stage, or it may divide into new individuals. It may also give rise to many small motile cells which unite in pairs and then grow up into mature plants. During the resting stage a bright red colour similar to that of the eye-spot may pervade the whole cell in the case of some forms of Chlamydomonas, so that the water in which these micro-organisms occur may become quite red. In Arctic regions and sometimes in the Alps one may come across extensive stretches of snow which seem almost coloured with blood. This so-called "red snow," which for a time puzzled all observers, is now known to be due to myriads of

rounded red cells of a microscopic organism called *Sphærella nivalis* (little sphere of the snows), which is closely related to Chlamydomonas and is capable of living and growing at very low temperatures, aided perhaps by the heat which the red colouring matter absorbs from the bright rays of the sun. It seems wonderful that any plant, and indeed so minute and unprotected a form as Sphærella, should be capable of growing at so low a temperature and resist the extreme cold of the nights in Alpine heights.

While Euglena and Chlamydomonas pass the greater part of their existence in the motile condition as free-swimming organisms and must therefore be considered as essentially aquatic, the organism which causes the so-called "red snow" occurs usually in the rounded, non-motile condition, though in melted snow it may form cilia and swim about. It is therefore tending to become terrestrial in habit by the conditions of its existence.

Another very primitive vegetable organism seems to have lost its motile stage altogether. On the trunks of trees, particularly on the west and north side and under moist conditions, sometimes also on wooden palings, a damp green filmy growth may be observed. If a little of this is scraped off and examined under the microscope it will be found to consist of innumerable small, non-motile green cells often in clusters, like those in fig. 1, *c*. The cells contain several green chlorophyll bodies, shaded in the drawing, and have very thick walls. This organism

has been called Pleurococcus, and we have reason to believe that it is descended from motile ancestors in which the non-motile has become the permanent rather than the temporary phase of its existence. This non-motile condition is more suitable for life out of the water, for cilia are of no use except in water. So fixed has this condition become in the case of Pleurococcus, that it does not produce cilia even when placed in water. It has, however, greatly increased the thickness of its cell-wall, so that it can resist the drier conditions to which it is of necessity exposed during certain periods of the year.

No account of the most primitive plants would be complete without mention of the remarkable microscopic plants called Diatoms, the well-known objects of study by microscopists on account of their beautifully marked tests or shells, which are almost imperishable as they are built up of silica, the brittle and transparent constituent of glass. This character indeed, namely, the fact that their outer wall is composed of mineral matter and not of the organic substance called cellulose, which forms the cell-wall of other plants, distinguishes them from all other vegetable organisms.

In fig. 1, *d* you will see on the left a side view of the organism and can observe that the two shells which form the outer covering of the diatom fit one over the other, like the lid over a pill-box. In surface view, as seen in the right-hand drawing, the shell may be oblong, round, triangular, or of various

shapes and marked with a variety of more or less intricate and beautiful patterns. Inside these hard cases is the living plant-cell with a brown or greenish-brown coloured body or bodies, which are shaded in the drawing. These diatoms are found in both fresh and salt water, sometimes swimming about, sometimes fixed to water plants or seaweeds, sometimes floating in lakes or in the sea. Here they occur often in enormous quantities, so as to give a greenish or brown tint to the water. Like Euglena they show a certain periodicity in their appearance, being found in particularly large numbers in spring and autumn and less commonly in the hot summer months. The cause for this periodicity is not clearly understood, but is probably due to their better nutrition in our lakes during spring floods and autumn rains, and in the sea to varying degrees of salinity (*i.e.* concentration of salt) caused by flood-waters or melting ice. They have a remarkable power of resisting cold, and are found in Arctic seas among floating ice. Indeed they prefer the colder seas. These floating diatoms form a very important part of the food of fishes, more particularly of the young fishes and other marine animals, and the distribution and periodicity of these microscopic plants has therefore been closely studied by fishery experts. The floating of these diatoms is often aided by long, spiny processes which some of them bear and also by small oil drops which are found in the cells. Diatoms, like other green plants, produce some of those very important sub-

stances called vitamines, which are so useful in promoting growth and preventing disease. Oil-drops seem to have a great power of attracting and retaining certain vitamines. Cod-liver oil is known to be particularly rich in one of these, and though the codfish does not feed on diatoms, it preys on small fish and other marine animals which have lived on diatoms. We may therefore conclude that the richness in vitamines of the oil found in the liver of the cod is probably due indirectly to the vitamine-forming power of the floating diatoms of the sea.

It was stated above that the shells of diatoms were practically imperishable. When the living diatoms die the shells sink to the bottom of the pond, lake, or sea in which they have been living, and there accumulate in vast masses, as year by year their number increases. In dredging the sea-bottom great stretches have been shown to be composed of what is called diatom-ooze or mud consisting of myriads of shells. When this mud becomes transformed in the course of ages into rocks, we may get seams of rock sometimes 50 feet in thickness consisting of a mass of minute diatom cases. We come across such deposits marking former lakes or sheets of water which have been dried up. At the northern end of the island of Skye in Scotland there occurs an unusually pure deposit of such diatomite (or Kieselguhr) covered with recent peat and turf, and extending over an area of 58 sq. miles. It marks the site of a former lake or sea. The fine microscopic shells as hard as

flint or glass, being like these substances composed of silica, are in this fossilised or semi-fossilised condition used for polishing, the rock being broken up into a fine powder.

Thus it will be seen that diatoms, minute and primitive as they are, have not only great beauty but also may be most useful as food for fish and therefore indirectly food for us, and even when dead their shells may be of use to us.

A consideration of the various types of primitive plants described in this chapter will show us that, however diverse they may be in shape and structure, they all possess this fundamental feature in common, that they consist of a minute portion of living substance called protoplasm, which contains one or more rather denser bodies coloured green with so-called chlorophyll (leaf-green), though this colour may be masked in the case of the "red snow" organism by the addition of red colouring matter, and in the case of diatoms by a brown substance. The possession of this green colour is a characteristic feature of both the lowest and the highest types of vegetation, and it enables all of them when exposed to light to build up those organic substances which are necessary for their life and growth. This is one of the essential differences between plants and animals.

CHAPTER II

SEAWEEDS

SEAWEEDS will be familiar to all who have visited the seaside, particularly if the coast was rocky or stony. They may be green, red, or brown in colour. The green seaweeds are found comparatively high up on the shore, and are particularly common near the mouths of rivers or covering the piles of harbours, where they are more or less protected from the battering of the waves. For they have very delicate fronds which are easily torn. One of these with a broad frond has sometimes been called Oyster Green, as it is often found attached to oyster shells. It might also be called Sea-Lettuce, as its Latin name is *Ulva lactuca*. It is sometimes eaten and is known under the name of Green Laver. Being very delicate, it is able to flourish in rockpools, where the plants are not so much exposed to the beating of the waves. It reproduces by the development in some of its cells of minute ciliate spores, which when liberated into the sea-water swim about by the movement of their cilia or threads very much like the microscopic Chlamydomonas described in Chapter I. Indeed it is often suggested that its motile reproductive

cells represent the ancestral condition of the plant, while the non-motile frond represents the resting condition of the plant, which stage we have seen occurs also in primitive motile organisms. When the motile reproductive cell of Ulva, the Sea-Lettuce, comes to rest, it fixes itself to some shell, rock, or other solid body and grows up into a large green frond. Thus the motile condition is a comparatively short phase in the life-history of the plant which in its development may be regarded to pass through the early stages of its evolutionary history, very much as a frog in its development passes through the aquatic tadpole stage, breathing with gills like a fish does.

Red seaweeds are generally of a delicate nature, often composed of slender, branching threads, sometimes like finely expanded moss-plants, or they may be more solid and of the consistency of cartilage. In all cases the red colouring matter is present in addition to a green or greenish-yellow colour. The green colour, as I mentioned in Chapter I, gives the plants the power of manufacturing some of the organic food material which the plant requires for its nutrition. The more delicate of the red seaweeds are found in the rock-pools, where they are not only protected against the dashing of the waves, but are also not exposed at low tide to the dry air, as they would be if they grew on the open shore. Only the more robust forms can resist such exposure during low tide, the tender ones remain covered by water in the rock-pools. These rock-pools are often

fringed by curious little growths that look like corals and are called coralline seaweeds. They are really red seaweeds in which the delicate plant-body has been covered in or encrusted with carbonate of lime, so as to render them hard and resistant both to the beating of the waves, and also to the drying of air and sun. There are, of course, fine pores through which the water can reach the plant-body beneath the protective covering of lime.

Those who wish to make collections of the beautiful red seaweeds should try the following method. Wash the seaweeds in fresh water to get rid of all the salt, then float them out in water in a saucer if small or on a plate if larger, having placed in the saucer or on a plate a piece of stout writing-paper a little larger in size than the seaweed. Bring this up slowly and gently until it touches the seaweed, and spread the latter out carefully with a pin or other pointed instrument. Lift the paper out and drain off the superfluous water by pinning it up by one corner. When nearly dry, the paper may be placed to straighten it out between sheets of absorbent paper such as blotting-paper and pressed. Care must, however, be taken that the seaweed is sufficiently dry and does not stick to the absorbent paper, for it is covered with mucilage, which gums it on to the mounting paper.

The brown seaweeds are the largest and the best known marine plants. They lie about in large tangled masses on the foreshore, mainly between the

limits of high and low tide ; but some extend above high-tide mark and some grow below the lowest low tide. The average high tide is marked on rocky shores by a white line of barnacles ; for these require to be wetted periodically by the sea. Above the line of barnacles some small tufts of a brown seaweed a few inches in length can be observed. This form, Pelvetia by name, is very drought-resistant, its fronds being during dry weather more or less rolled round to form a groove or channel on the sheltered side near the rock. In this groove a certain amount of moisture is retained for a long time. Of course at exceptionally high tides it is wetted by the sea and during stormy weather by the spray. The comparatively adverse conditions under which it grows cause it to remain comparatively small. At the other end of the series we have the largest seaweeds which grow attached to rocks below low-water mark, and are only occasionally and partially exposed to the air. These are the large Tangles sometimes cast up on the beach. They are anchored to the rock by numerous holdfasts looking like roots, and have a round and elastic stem. Attached to the latter is a frond several feet, and, indeed, sometimes several yards, in length. The fronds are sometimes used as vegetable barometers, being supposed to foretell fine weather when they remain dry and hard and bad weather when they become soft. These changes are really due to the fact that when the atmosphere is damp, even slightly so, the salt which the fronds

contain absorbs moisture and renders them moist and limp, while in dry weather the plant loses moisture, and as the walls of its cells are gelatinous they become hard. On the Pacific coast of America some of the brown seaweed allied to our tangles

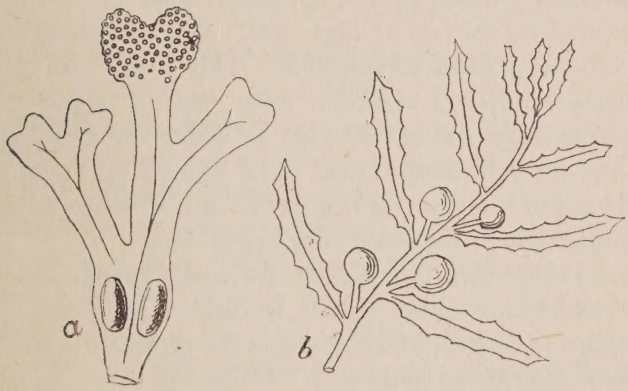

FIG. 2.—*a*, frond of the Bladder-wrack, showing two of the floats or bladders and a median fertile frond with the wartlike projections within which the reproductive cells are formed; *b*, portion of a sterile frond of the Sargasso Weed, showing leaf-like segments and stalked berry-like floats or bladders.

grow to an extraordinary size, being as much as a hundred or more feet in length. The stem of such a seaweed may be as thick as a man's arm, and is often buoyed up by a hollow float as large as a small cocoa-nut. The majority of the brown seaweeds occur on the foreshore between the high- and low-water line, and lie tumbled about on the rocks to which they are attached by a disc-shaped sucker. They are comparatively tough, consisting of repeatedly branched

fronds, often having a distinct midrib, as can be seen in fig. 2, *a*. This drawing represents the terminal branch of the common Bladder-wrack as it is called, *Fucus vesiculosus*, because it possesses bladders or vesicles by means of which it is buoyed up when covered by water, so that the plants stand erect when covered by the sea at high tide. Some other kinds of Fucus possess no bladders. This is the case, for instance, with a common form with a jagged or serrate edge (*Fucus serratus*), in which the frond is, however, sufficiently broad to be buoyed up without the aid of bladders, as is also the case with our large tangles which possess a very broad frond.

All these brown seaweeds are really green plants in which the green colour is hidden by a brown colouring matter, which obscures the green and makes them look greenish-brown. If one of these brown seaweeds is plunged for a short time into hot water, the brown colour comes out and the plant will look comparatively green. The green colour cannot be extracted with hot water, but is readily soluble in alcohol, as is the case with the green colouring matter or chlorophyll of other plants.

It will have been noticed by those who have clambered over rocks covered with brown seaweeds that these are very slippery when wet. This is due to the fact that the fronds are covered when moist or immersed in water with a coating of slime or mucilage, which acts as a lubricant and prevents the plant from being injured when knocked about against the

rocks during rough weather. On the other hand, when exposed to dry conditions at low tide the mucilage hardens and protects the plant against loss of water. It is the hardening of the mucilage outside the plant which makes the seaweed so hard when dry.

The tips of the branching fronds, as you can see from fig. 2, *a*, are often swollen and marked with wart-like projections. If these are carefully examined with a lens it will be seen that each of these has a minute aperture which leads into a small cavity, and if a section of this part of the plant is examined under the microscope it will be seen that the hollow chamber, or conceptacle as it is called, contains the reproductive cells of the plant. When ripe these reproductive cells ooze out from the pores, when the frond contracts as it does when lying on the beach at low tide. The greenish or orange-coloured slime which pours out of these conceptacles contains reproductive cells of two kinds. Both are microscopic in size, but the larger ones are round and contain a considerable amount of food material. These are the egg-cells. They are brown in colour and float away in the sea-water when the tide comes in. The smaller reproductive cells are of an orange colour and are provided with a pair of thread-like cilia, by the active movement of which they are able to swim about in the water. They seem to be attracted by something which diffuses out into the water from the egg-cells ; for when observed under the microscope they con-

gregate in large numbers around the larger egg-cells, often imparting to the latter a rotating movement by their joint activity. One of these small motile bodies, antherozoids they are called, enters the egg-cell and thereby fertilises it. The egg-cell then drifts away until it comes in contact with a rock or other suitable solid object, to which it becomes fixed, dividing into two cells, one of which gives rise to the holdfast or sucker and the other into the bifurcating frond of the new plant.

I have represented in fig. 2, *b* another brown seaweed which is of considerable interest. You will see that it has some more leaf-like fronds than Fucus, and also little, stalked, spherical bodies which look like berries but are really hollow bladders or floats filled with air. The sketch represents the so-called Sargasso weed (*Sargassum bacciferum*), which occurs in enormous quantities, covering many thousands of square miles in the Atlantic and forming the Sargasso Sea, so called by Columbus and the early Spanish navigators, whose small sailing vessels were often impeded in their course by the accumulation of this seaweed. The Sargasso Sea, however, is not the home of this seaweed, which is really not a floating plant but grows attached to the rocks of the West Indian islands and generally around the Gulf of Mexico. Torn off by storms, this seaweed floats away and is carried by ocean currents, largely by the Gulf Stream, and is occasionally washed up on the Irish coast. But it travels mainly farther south,

and gradually accumulates in that large area of comparatively still water in the Atlantic, between the westward-flowing Gulf Stream and the easterly current from North Africa. The Sargasso weed neither grows actively nor reproduces while floating in this way, but it forms abundant food for a variety of marine animals and many are found amongst its fronds or attached to them.

In dealing with the green seaweeds, I mentioned that they were occasionally eaten in Scotland. From one of the red seaweeds (Porphyra) a condiment called Laver is prepared which has a taste like olives, and though relished by some people, is distasteful to others. Carrageen or Irish Moss, hard when dry, is very mucilaginous or gelatinous, and has been used for making soups and jellies and also medicinally for cough mixtures. With the exception of one form which is eaten in Chili, the brown seaweeds are too tough to be used for food, but they were formerly dried and burnt, and their ashes, known as kelp, being rich in soda and potash, were formerly used for the manufacture of coarse soap and also of glass. Kelp was also formerly used as a source of iodine. Modern chemical methods, however, have found better sources for these substances, and the brown seaweeds are now only used as manure. In some parts of Scotland and Ireland they are still very important in this connection, and when properly applied have good manurial value.

CHAPTER III

MUSHROOMS, TOADSTOOLS, AND MOULDS

In the preceding chapters I have given you an account of some more or less simple aquatic plants which were characterised by the possession of green colouring matter, a substance essential to plants if they are to nourish themselves from inorganic substances dissolved in the fresh or salt water. The green colour, you will remember, may be masked in some plants, like the red and brown seaweeds, by red or brown colouring matter. Still these must be regarded essentially as green plants. In all of these the green colouring matter absorbs certain definite rays of light, which are transformed in the plant into energy, and the latter enables the plant to build up the organic matter necessary for its nutrition and growth. In the first instance these substances are of the nature of sugar and starch. Plants which do not possess chlorophyll are unable to build up these substances for themselves, and are, therefore, dependent upon the food material manufactured by green plants. A whole group of such non-green plants exists among the simpler Flowerless Plants. These are called fungi, and include such forms as mushrooms, toad-

stools, and moulds. Though they are all without green colour, they may possess other and often brilliant colouring, mainly yellow, orange, scarlet, or purple. The Common Mushroom is white, but pink on the under-surface when young and fresh, changing into black as the mushroom grows old. What we know as mushroom is only the fructification which appears above ground. Below ground the mushroom is attached to delicate white threads, which branch out to a considerable distance from the fruiting part of the plant. These threads, represented at the base of the stalk in fig. 3, form the absorptive part of the plant, like the roots and root hairs of the higher plants. But, unlike the latter, they are mainly concerned in absorbing organic matter, that is, substances resulting from the decay of vegetable and animal matter. In nature decaying leaves and animal droppings form the chief source of food of mushrooms and toadstools. Mushrooms can be grown from so-called mushroom spawn, in the form of bricks of hardened manure containing the ramifying, absorptive threads or mycelium of the fungus. These bricks or tablets are broken up and mixed with fresh manure, which by its decomposition produces the necessary heat, and being rich in organic substances supplies the fungus with the necessary food material, until it has absorbed enough to produce the fructifications. These seem to spring up above ground with great rapidity, because we do not see the very slow development of the underground portion of the plant. At

first a small round mass of closely interlacing filaments is formed just below the surface of the soil, and this very rapidly grows into the little button mushroom within which by a circular splitting a

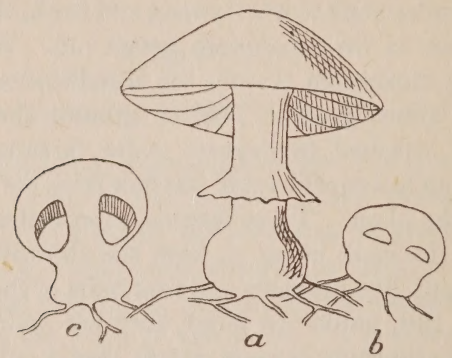

FIG. 3.—Diagrammatic drawings of a mushroom. *a*, mature fructification showing the gills on the under-surface of the cap or pileus. The stalk bears a fringed ring or annulus; *b*, section through a young button-mushroom showing the ring-like split into which the gills will later grow; *c*, a rather older mushroom showing the developing gills (shaded). The cap or pileus is still joined to the stalk by a thin membrane, which when it splits close to the gills will remain as an annulus around the stalk.

cavity arises (see fig. 3, *b*) for the production of the spores, by means of which the mushroom is spread into new regions. The button mushroom develops a stalk which by rapid extension brings the cap of the mushroom above ground, where the latter expands, often leaving a ring-like mass (the annulus) around the stalk indicating where the edge of the cap or pileus has split away from the stalk. On the

under-side of the cap are a series of narrow plates or gills on which the spores are borne. These are extraordinarily numerous, and it has been estimated that a single mushroom may produce as many as 5,800,000,000 spores. These are very small and light and are carried away even by quite gentle currents of air. Being produced in such large numbers, and often of distinct colours, it is easy to obtain a picture of the arrangement of the gills of a mushroom by cutting off the stalk, and placing the cap or head with the gills downwards on a piece of white paper which has been covered with gum. If the cap is removed next day, a clear white print of the gills will be obtained, as the intervals between the gills will be covered with the spores that have been shed from their surface. In fig. 3, *c* you will see that the gills are still covered in by a veil-like arrangement which breaks away as the head enlarges, leaving generally a torn ring or annulus around the stalk. Though the fructification of mushrooms is produced above ground it is not essential that they should be in the light. They can be cultivated in dark caves, disused mines, and cellars, as is regularly done in France and in some places in England. In France mushroom-growing was an extensive industry before the war. The daily production in Paris alone was about 24 tons, so that the total value amounted to about nine million francs a year. But the increased cost of labour, the shortage of manure owing to the use of motor transport, and

the appearance of insect pests has greatly increased the cost of production, and consequently fewer are grown. In England the cultivation of mushrooms has always been on a much smaller scale. However, in several places disused quarry tunnels are being used for this purpose, as at Carsham in Wiltshire. The area here available is over 20 acres, capable of producing 250,000 lb. of mushrooms a year. Over 40 tons of manure are used weekly, which will give some idea of the amount of organic food needed for the production of mushrooms.

Man is, however, not the only cultivator of mushrooms. Several kinds of ants, but particularly a tropical species called the leaf-cutting ant, are now known to cultivate in their underground nests various kinds of mushrooms. The leaf-cutting ant, as its name indicates, is an extensive destroyer of the foliage of plants, carrying away the pieces of leaves which it cuts off with its powerful jaws to its nest. It was for a long time not known what it did with these pieces of leaves. Now we know that they are chewed up into pellets, with which the ant builds up its mushroom beds, just as we make up beds of manure for mushroom-growing. The suggestion made by the great naturalist Belt, who explored the vegetation of the Amazon, has been found to be correct. He stated it as his opinion that these ants were mushroom growers and mushroom eaters, and this turns out to be true. The same is the case with some of the termites or white ants, whose tall

nests made of mounds of earth contain intricate chambers in which fungi are grown for the food of the ants.

The name of toadstool is often given to mushroom-like growths which are poisonous. This is, however, not correct, as there are many edible forms of fungi very different in structure from the common mushroom and many poisonous forms nearly related to it. On the Continent a great many more forms of fungi are eaten than in this country. The markets abroad are regularly inspected by someone who knows the various kinds of edible mushrooms, and at St Etienne in France, for example, some twenty-two different kinds are allowed to be sold. In this country only a small number can be said to be commonly used. They comprise the common Field Mushroom, the Horse Mushroom, a larger and coarser form, the Blewitt, the Common Parasol Mushroom, and the so-called Puff-Ball when very young. It is a pity that more are not made use of. No doubt the difficulty of distinguishing between edible or poisonous forms is the main difficulty, and great care is needed for they are often very much alike.

Mushrooms and toadstools are often associated with the occurrence of the so-called fairy rings. The formation of the latter is due to the fact that when the mushroom begins its growth its filaments radiate out in every direction in search of food material, and, as we have seen, it is only the organic food material, *i.e.* decaying vegetable or animal matter, which is

of any use for the nutrition of the plant. As it spreads outwards, therefore, the central part of the plot on which it is growing becomes exhausted of the necessary food material, and the fungal filaments die away in the centre leaving a ring of fructifications at the edge, which marks the limit reached underground by the absorptive part of the plant. Next year the underground part of the plant pushes farther outwards, forming a still wider circle, because the mushroom has absorbed all the food material within the circle. Some American observers who have been studying the formation of fairy rings have noted the rates at which these circles extend. They average about a foot per year, and from the width of some of these fairy rings they have calculated that some of those observed must have been from 250 to 400 years old.

Some mushrooms and toadstools, particularly some which send their absorptive filaments in search of food into the wood of dead trees, have been known to be luminous at night, and they also render the rotten wood on which they are growing luminous. At one time it was thought that they absorbed light during the day and gave it out at night. But it is known now that they are luminous even when kept permanently in darkness. It was then thought that it was a peculiarly active respiratory process of the fungi that caused the production of light in these plants, just as breathing produces heat in our bodies. This does not, however, seem to be the case, though

the luminosity only takes place in the presence of oxygen. It is now thought that the luminous fungi produce a substance which may be termed photogen (light producer), of which we do not as yet know the chemical nature, but which in the presence of oxygen undergoes a kind of combustion, with liberation of light, very much as phosphorus produces phosphorescence.

Some of the toadstools which feed on dead wood may be very destructive. That is the case with the fungus that causes "dry rot." This fungus (*Merulius lachrymans*) first attacks wood when it is damp, sometimes already in the timber-yard. But once the delicate absorptive threads have entered the wood it can go on growing even if the wood is quite dry and made up into joists, flooring, stairs, etc. Usually, however, it only gets a hold on the wood if there is no proper ventilation. Then it destroys the wood entirely until it breaks up into little square pieces. It is most difficult to get rid of once it has attacked the woodwork of a house, and often does very extensive damage. Usually its fructifications are not seen, but when it forms them it produces great spongy cushions with myriads of spores which, carried by currents of air, can attack new pieces of wood. They can, however, only germinate under damp conditions.

I must now pass on to deal with the moulds, which are very small in comparison with the mushrooms. The figure of the Blue Mould (*Penicillium*) shown in

fig. 4 is very greatly enlarged, for it is almost microscopic. It consists of minute and delicate threads which branch and ramify in every direction, and penetrate into whatever substance affords suitable food for this plant. Damp bread, jam, potato, and indeed any dead organic matter, but particularly vegetable matter, affords a suitable medium upon which moulds can grow. When they have absorbed sufficient nutriment they commence to develop their fructifications. These in the case of the moulds are exceedingly simple, and in the specimen I have drawn the fructification consists of erect, branching filaments, very like a miniature brush, from the ends of which innumerable, minute, rounded spores are budded off. These, produced in their hundreds and thousands, are carried away by the slightest puff and are always floating about in the air. Whenever they fall upon a suitable damp medium they begin to grow and develop into branched filaments, and hence it is that we cannot leave food about for long without its going mouldy. It is particularly in a still or confined atmosphere that moulds grow rapidly, and in warm rather than in cold weather. Should the conditions become unfavourable for the further

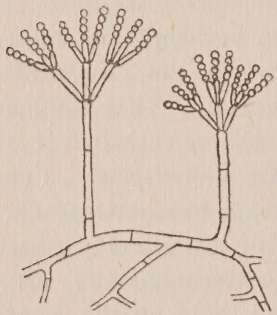

FIG. 4.—Magnified representation of the spore-producing filaments of the Blue Mould (*Penicillium*).

growth the Blue Mould produces small, round fructifications, protecting with their hard outer wall a group of resting spores, which only germinate after a considerable interval of time and when the conditions are again favourable for the growth of these fungi. There are many kinds of moulds, some of which are known by the colour of their spores like the blue and green moulds. These latter are sometimes encouraged to grow in certain kinds of cheese like Stilton and Gorgonzola, to which they supply some of the characteristic flavour which lovers of these cheeses enjoy.

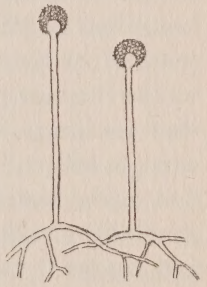

Fig. 5. — Magnified drawing of the fructification of the Pin Mould (*Mucor*).

The White or Pin Mould (*Mucor*) is so called because of the white fluffy growth it forms with little black pinhead-like structures found on the tips of upright filaments and in which the spores are contained. The mycelial threads of this mould are frequently found on animal dung, but also on other substances. This fungus, too, can form thick-walled resting-spores, which have the function of preserving it during periods in which the conditions are adverse to vegetative growth. The resting-spores of this mould are formed by the union of protoplasm of the tips of two adjacent filaments, which by fusion form the so-called zygospore.

Mushrooms and moulds are botanically called

saprophytes, which means plants living on dead organic matter, but there are a great number of other fungi which are parasites, that is, they feed on living organisms. Most of these are the cause of various plant diseases such as the Smut of oats, the Rust of wheat, the Wart disease of the potato, and many others. In all these cases the absorptive part of the fungus ramifies in the living stem or leaves of the host-plant on which the fungus is parasitic, destroying some of its living substance, in some cases actually killing the host-plant. Thus it is found, for instance, that seedlings which are over-watered often die of what is called "damping off." This is not directly due to the water, but to a fungus in the soil which generally attacks the seedling just above the soil and causes it to become sickly and fall over on the ground. In some instances a fungus may be parasitic on animals. The Salmon Disease is due to a parasitic fungus which grows in the skin of the salmon and produces a white furry growth upon it, and a very similar fungus often causes the death of goldfish. Flies and insect larvæ may be attacked and killed by fungal parasites, and in some cases, after they have killed the caterpillars, they grow out of their heads like horns, often bright orange in colour.

Thus we see that while mushrooms and moulds live on dead and decaying organic matter, they are related to many fungi which may become very harmful by destroying or at least injuring

many of our useful crops like wheat, oats, and potatoes.

A point of interest connected with the plants mentioned in this chapter remains to be dealt with. It is obvious from the fact that they do not possess the green colouring matter of ordinary plants, that they cannot manufacture the organic matter of which they consist and which they need for further growth from the inorganic matter around them. They are therefore dependent upon already formed organic matter, and are either saprophytic or parasitic. They cannot, therefore, be very primitive plants, as their existence presupposes other more primitive green plants on the organic matter of which, either dead or living, they feed. We must therefore regard all fungi to which mushrooms, toadstools, and moulds belong as being derived from green plants which have taken to a specialised mode of life and have lost their green colour. This has happened not only among the lower groups of plants, but many Flowering Plants such as the Dodder and Toothwort among our common British plants have become parasitic, and taking up organic food matter, they no longer require chlorophyll and consequently no longer produce green colouring matter. The fungi with the simple organisation of their vegetative structure are supposed to have descended from primitive green plants like the aquatic Algæ, which include the seaweeds and similar fresh-water weeds, and having become saprophytic or parasitic they

have lost their green colour, as chlorophyll was of no further use to them. We have indeed many indications that this is the case, and also some evidence that they have descended not from one but from several different groups of Algæ.

CHAPTER IV

BACTERIA, THE MOST MINUTE PLANTS

LIKE the simplest forms of plant life of which I dealt with in the first chapter, Bacteria are entirely microscopic. They are indeed much smaller than the previously described green aquatic plants. For whereas some of those were about one five-hundredth of an inch in diameter, bacteria, though they may vary in size, are commonly about one twenty-thousandth part of an inch in length, so that except with the very highest magnifications they appear like minute specks even under the microscope. Fig. 6, *a* reproduces some of the shapes they may present; they may be round or oval, rod-shaped or spirally twisted. Though so minute that they cannot be readily seen, they can often be distinguished by their movement produced by the vibrations or lashings of the threadlike cilia which may be borne at one or both ends of the body; sometimes quite a bunch of these cilia occur together. The bacteria dart hither and thither and twist about if they are of spiral shape, like minute corkscrews in an apparently erratic manner. We know very little of their internal structure, for they are too small to be easily examined, but from time to time one notices

some in which there are very distinct rounded bodies, either dark or refringent. These are the spores by means of which these minute plants are distributed by currents of air from one place to another. If the plants themselves are small, the spores are obviously still more minute, and when the cell in which they are produced dies off, the spores are carried about by currents of water, or if dry even by slight currents of air, and are found practically everywhere. Every time we breathe we take in some of these spores, and every drop of water we drink contains some, for they are found both in the air and in water.

These spores are very resistant. They can remain for a long time in perfectly dry air without losing their power of germination, and they can resist both very low and very high temperatures, though the majority of them are killed in boiling water. When they get into suitable conditions for growth the spore rapidly develops into a small vegetative cell, and if there is an abundant supply of food material the cell grows in length and then splits up into two cells. Each of these increases in size with great rapidity and repeats the process of division. This constant splitting up of one individual into two, or fission as it is called, which is characteristic of bacteria, explains the extraordinary rapid increase in the number of bacteria when in a suitable nutritive solution. Supposing a bacterium divided into two in this way once every hour, so that there would be two at the end of one hour and four at the end of the second hour, and so on,

in the course of twenty-four hours there would be over ten million in the place of the single individual with which the growth started. This will give some idea of the extraordinary rate of multiplication. Of course we are supposing that the bacteria are constantly supplied with sufficient food material. What is the nature of this food material? That will differ for different kinds of bacteria; but speaking generally we may say that they require some kind of organic matter, that is, some of those complex substances which are built up by plants and animals and of which the plants and animals are mainly composed. Bacteria are really the smallest forms of that group of plants which we term fungi and of which the mushrooms and toadstools are the largest members. Like these the bacteria are devoid of green colouring matter (chlorophyll), and are consequently dependent upon organic matter for their nutrition. They are, therefore, found largely in dead vegetable and animal remains, and they are the chief organisms which cause the decay and decomposition of these bodies. In doing this they are fulfilling a useful purpose. For what would happen if all the plants and animals that died did not decay away? The world would soon be covered with their remains. Moreover, the existing vegetation derives its food from the decay of previous vegetation. Thus the bacteria prepare the soil for ordinary plants. When we manure our fields, we put into them the litter of horses or cattle, consisting partly of animal and partly of vegetable

matter, and these organic remains are changed into simpler substances more suitable for our crops by the activity of decay producing bacteria. These are, therefore, very useful to us in the cultivation of our crops, just as they are useful to the natural vegetation by helping to enrich the soil. They, as well as the higher fungi, cause the decay of the leaf mould in the forest, and so enable not only the trees but the bluebells and bracken to get much of the nutriment they require.

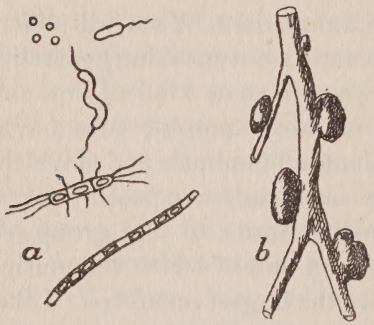

FIG. 6.—*a*, various forms of bacterial cells very highly magnified. Several are motile forms and possess cilia. Two of them are seen to contain oval spores in their cells; *b*, root of a plant belonging to the Pea family showing the characteristic root tubercles which contain nitrifying bacteria.

Some kinds of bacteria further the growth of plants in a very special way. All plants require for their growth a chemical element called nitrogen, which is one of the main constituents of the air, but which the ordinary plants cannot make use of in that form any more than we can, though we too require this substance to build up our bodies. Plants take up nitrogen in the form of compound substances called nitrates, which are found in the soil and which, dissolved in water, are absorbed by their roots. But

how do the nitrates get into the soil? Here the bacteria come to the aid of the higher plants. A certain number of bacteria have the power of causing the nitrogen of the atmosphere, which penetrates between the particles of the soil, to combine with the oxygen of the air to form the nitrates. These nitrifying bacteria are constantly at work in the soil replenishing it with the nitrates which our crops, and particularly our cereal crops, take out of it. If a field is allowed to lie fallow, that is to say, if no crop is grown on it, it will be found to be greatly enriched in nitrates by the activity of the nitrifying bacteria of the soil.

In some cases bacteria form a very close association with the higher plants. If we pull up with its roots a pea or bean plant or indeed any plant belonging to the pea family, such as the clover, vetch, or lupin, we find its roots bear curious swellings or tubercles which on microscopic examination are found to contain innumerable minute bacteria. By experiments it has been found that plants provided with such root tubercles (see fig. 6, *b*) are capable of growing in a soil completely devoid of nitrates, since by the activity of the bacteria in the tubercles they can make use of the nitrogen found between the particles of the soil. Indeed it has become customary to grow a leguminous crop, that is, a crop of plants belonging to the pea family, after the soil has become exhausted by a crop like the wheat, which takes so large an amount of the available nitrates out of the soil. This

practice of alternation or rotation of crops—one like the wheat impoverishing and one like the pea enriching the soil with nitrates—is extremely important for good agriculture. We may say that a crop of beans or peas enriches the soil in nitrates, for though a large quantity of nitrogenous food will be stored in the seeds of these plants and will be taken away when we harvest the crop, the roots, and particularly the root tubercles, remain or will be ploughed into the soil, and when they decay away they will liberate a considerable amount of nitrogenous matter.

In addition to these useful bacteria there exist also harmful ones, for we have both friends and foes among these micro-organisms. Many bacteria are parasitic, that is to say, they are found in living plants or animals, as is the case with the larger fungi mentioned in the last chapter; such parasitic bacteria are the cause of many diseases, both of plants and animals. Most of our infectious diseases are caused by bacteria, either in our blood or in various organs of the body. From what is said above about the minute spores being so readily carried by the air, you can gather how infection travels. You may breathe in the germs, as the spores of these bacteria are sometimes called, or you can get them through water or milk which you drink or food which you eat. Indeed it seems marvellous that we escape any infectious illness. Luckily our body if in a healthy condition can destroy a great many of the germs and thus prevent the disease from attacking us.

Even when we are attacked by an illness and the germs multiply in our blood, certain small colourless corpuscles in the blood are busily engaged in absorbing and destroying these germs. Nevertheless, it is best to prevent their entry into our body, and this is sometimes likely to occur through cuts or wounds. It is therefore important to wash wounds with some antiseptic substance, that is, something which will kill the germs. In former times this was not done and a very large number of people died of blood poisoning. Lord Lister, the great Edinburgh surgeon, was the first to introduce the practice of antiseptic treatment of wounds in England, and also the sterilising of all instruments and bandages used in operations. By so doing he saved thousands of valuable lives.

It is important, too, to keep kitchen and dairy utensils clean and free from both decay and disease-producing bacteria. This can be done by proper sterilisation with boiling water, which kills not only the bacteria but destroys also most of their spores.

Mention must now be made of certain changes which take place in liquids when special kinds of bacteria get into them. It is a well-known fact that milk sometimes turns sour, particularly in hot summer weather. This is due to the presence in the milk of certain bacteria, which in hot weather multiply with great rapidity and break up the sugar of milk into an acid called lactic acid, the latter giving the milk

a sour taste and also causing it to become thick and curdy. Another bacterial organism causes the souring of wine by producing acetic acid or vinegar. Such changes are caused by the action of the bacteria upon the liquid in which they are growing and are called fermentative changes.

There are, however, besides bacteria, other fermentative organisms, the most common of which is the so-called yeast-plant, which is used in the manufacture of beer. It is not a bacterium, but a fungus more nearly related to the mould I spoke about in the last chapter. Brewers' yeast consists, as you will see from fig. 7, of a number of rounded or oval cells which remain loosely attached to one another. Though microscopic they are much larger than bacteria, measuring approximately one three-thousandth part of an inch in diameter, about seven times as large as a bacterium. The yeast-cells increase in number not by splitting into two as do the bacteria, but by producing small outgrowths such as you can see arising from the two largest cells. The smaller cells in the figure are all buds of the larger cells which have become nipped off, but have not grown as yet

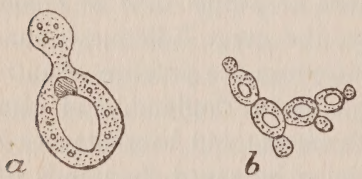

FIG. 7.—Yeast-cells. *a*, greatly enlarged view of a mature cell budding off a daughter cell; *b*, a group of cells, less highly magnified, showing the manner in which the budded-off daughter cells remain in contact when growing undisturbed.

to the size of their parent cells. In the larger cells is seen a round, clear space which contains a liquid, the so-called cell-sap. The cells are only loosely held together, and any movement of the liquid in which they grow will easily separate them. When such cells are placed in the wort, which is an extract of malt-sugar prepared from the germinated grains of the barley, the yeast-cells grow rapidly and vigorously, feeding on the sugar solution and also breaking up the sugar into alcohol and carbonic acid gas. The latter is given off in the form of bubbles in the liquid and causes the frothy appearance of a liquid containing actively growing yeast-cells. The alcohol, however, when it has accumulated in the liquid to a certain percentage, acts as a poison and stops further fermentation. The percentage of alcohol reached before fermentation ceases varies with different kinds of yeasts, some producing light beers with 3 to 4 per cent. of alcohol and some heavier beers with 5 to 6 per cent. Ginger-beer is also produced by a fermentative process in a sugar solution. In this case the barm, or ginger-beer plant as the barm is sometimes called, consists of a mixture of yeast-cells and bacteria. When this material is placed in a solution containing sugar, the yeast-cell ferments the latter, producing alcohol and carbonic acid, as in the production of beer. But then the activity of the bacterium comes into play, and seizing on the alcohol it breaks up the latter into carbonic acid and water. Thus the yeast-cell produces and the bacterium re-

moves the alcohol from the liquid, so that the resulting drink contains little or no alcohol.

It is interesting to note that these two organisms live and act together to their mutual advantage. The bacterium is dependent upon the yeast cells for the production of the alcohol on which it feeds, while the bacterium by breaking up and thus removing the alcohol from the liquid enables the yeast-cell to continue to develop until all the sugar has been used up. Such an interdependence of the two living organisms is called symbiosis (living together). There are other interesting cases of such symbiosis, one of which has been mentioned above in connection with the root-tubercles of leguminous plants. For though it was only mentioned there that the peas and beans were aided in their nutrition by the nitrogen fixing activity of the bacteria which inhabit the root-tubercles, the bacteria in the root are supplied with some of the organic matter they require, in the form of sugar, which the pea or bean plant forms in its green leaves and which is conducted down into the roots. In this way the leguminous plant and the bacterium act and react upon each other to their mutual advantage, and the bacterium must not be regarded as parasitic on the roots of the pea, but as symbiotic.

As in the case of the fungi so in the case of the bacteria, which also contain no green colouring matter, we are inclined to believe that their saprophytic or parasitic mode of life is not a primitive but

a specialised condition of nutrition and that they have descended from more primitive green plants. Some organisms of this kind, having many points of structure in common with the bacteria, actually exist and make up a group of so-called Blue-green Algæ, from which we may consider the bacteria to have been derived.

CHAPTER V

LIVERWORTS AND MOSSES

MOST people are familiar with mosses, but probably comparatively few have heard of liverworts. These are, however, closely related to mosses, though they are simpler in structure and more primitive in their organisation. The simplest liverworts are expanded green growths, which we find covering stones or soil, near streams or lakes, sometimes growing even on damp garden-paths. Such a green growth which does not show any distinction of stem and leaves is botanically spoken of as a thallus, or sometimes called a frond, though we must not confuse it with a frond of a fern, which is really a leaf. I have described in the previous chapter such a frond or thallus in the case of the brown seaweed or Bladder-wrack. This kind of vegetative structure is characteristic of primitive plants. The brown seaweeds may be considered primitive since they are marine plants and vegetable life probably began in the sea. The liverworts which have this simple frondose condition, though more advanced in structure, represent the simplest forms of *land* plants. The thallus of the liverworts, like that of the brown seaweed, branches by forking or

bifurcation. The simple thallus of a liverwort called Pellia, common on moist and shady banks, is represented in fig. 8, *a*. In some liverworts growing in drier places, such as Marchantia, the thallus is more elaborate in its structure. The surface in these forms

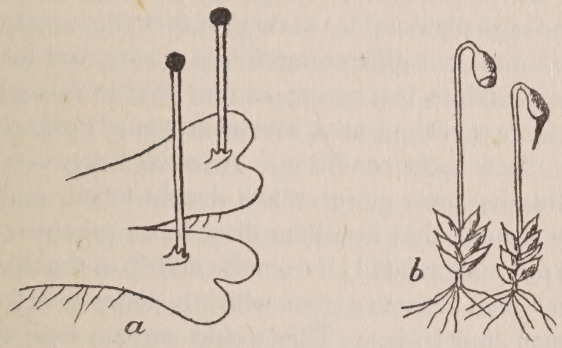

FIG. 8.—*a*, thallus or frond of a simple Liverwort, showing the absorptive hairs or rhizoids growing from the under-surface and the stalked spore cases arising from the upper surface ; *b*, two Moss plants bearing rhizoids at the base of their stems and pendulous spore-cases on a stalk arising from the top of the leafy stems. One of the spore-cases bears the peaked cap or calyptra, while the other shows the rounded lid, which closes the spore-case until the spores are ripe.

is marked with small lozenge-shaped areas which represent little air-chambers, each opening to the exterior by a minute pore. The frond or thallus is fixed to the soil by delicate hairs produced in large numbers on the under-surface, and these not only serve to fix the plant to the soil or stone on which it grows, but are also the absorptive organs by means of which the plant takes up water and any mineral

salts that may be dissolved in it. A few of the thalloid liverworts, such as Marchantia for instance, bear also small scales on the under-surface, which bending over the tip of the thallus may protect the delicate growing point from injury. I have said that the liverworts may be considered to be some of the most primitive of the land plants, since in most of them the vegetative structure is not differentiated into a stem and leaves. It is therefore interesting to find that in this group of plants we can observe several stages of progression towards a leafy condition. In some liverworts the thallus becomes more or less deeply lobed, and we may assume that in others these lobes became more and more segmented off from the midrib of the thallus, which then became a stem, while the lobes were transformed into leaves. This would explain how some of the liverworts became leafy, and in such forms the two rows of leaves which they possess may be considered to have originated in the first instance as lobes of the more primitive thallus. Some of these leafy liverworts, which represent the more specialised forms of this group of plants, have adapted themselves to very much drier localities than the frondose forms, and are found growing on dry stones on the open hillside or on the bark of tree-trunks. To be able to live in such dry positions several of them have curiously modified a portion of their leaves into minute cups or pitchers in which they can store water. These pitchers are in the shelter of the remaining portion of the leaf, so that the water does not readily evaporate.

Thus during wet weather they rapidly absorb water into the pitchers, and can store it up during more or less prolonged periods of drought. That these pitchers are really effective water-storing organs is proved by the fact that they are often inhabited by small water animals belonging to the group of rotifers, which have adapted themselves to live in these pitchers. In tropical forests where the atmosphere is generally very moisture-laden liverworts are very abundant, and minute leafy forms are often found growing upon the leaves of the trees, lifted far above the ground. At certain times, generally in the spring or summer, the thallus develops its reproductive organs, and then there appears lifted up on a delicate vertical stalk the small capsule containing the spores (see fig. 8, *a*). But preceding the formation of the spore-capsule, which is clearly visible to the naked eye, there are produced in the case of Pellia, which is the liverwort represented in fig. 8, close to the apex of the thallus, minute reproductive organs called archegonia which contain the microscopic egg-cells. These egg-cells are fertilised by still smaller motile reproductive cells similar to those which fertilise the egg-cells of the brown seaweed Fucus. It is from the fertilised egg-cell that the spore capsule grows, so that the life-history of the liverwort is really more complicated than would appear at first sight, when we see the spore-capsule growing upon the thallus. There is really a process of reproduction which is hidden from view. Since this process consists in the fertilisation of an

egg-cell by another so-called male reproductive cell or antherozoid, it is spoken of as a process of sexual reproduction. The spore-capsule, on the other hand, which arises from the fertilised egg-cell, produces spores which can germinate directly without any fertilising act. These spores are therefore called asexual. The liverwort, simple as it is, possesses two kinds of reproductive cells which alternate one with the other, the asexual spores of the spore-capsule following upon the sexual spores, borne more closely on the thallus.

The spore capsule of Pellia is not much bigger than a pin's head and generally dark green or black in colour. When ripe the spore-capsule splits open along four lines, and between the four valves the minute spores appear. The capsule opens only in dry weather by the contraction on drying of certain of its cells, and the spores are dispersed through the air. In the inside of the capsule there are at the base certain spirally twisted threads, called elaters, which are very sensitive to different degrees of moisture, and contract and expand as the air changes from a dry to a moist condition. By this alternating contraction and expansion all the spores are ultimately pushed out of the spore-capsule. If they have been carried to a suitable damp place they speedily germinate and grow into a new thallus, which by repeated branching in the manner shown in the drawing may soon cover a considerable patch of ground.

I have said that liverworts may be considered to be the most primitive of existing land plants. If so we might expect that they would be of considerable antiquity. Unfortunately they are so delicate in texture, since they possess no woody tissues, that their remains were not likely to be preserved in a fossil condition, and until a short time ago they were only known to occur as fossils in rocks of comparatively recent formation. A few years ago, however, some very well preserved remains were found in some of the carboniferous rocks, so that we now know that they used to grow in those vast swamp-forests which covered Lancashire many millions of years ago, and the remains of which we now burn as coal.

Let us now turn from the more primitive liverworts to consider the true mosses, which we also associate with damp, shady situations, though some of them occur in comparatively dry places like the tops of walls, bare rocks, or on the stems and branches of trees. If we compare the moss plant as represented diagrammatically in fig. 8, *b* with that of a liverwort, we see that it is more specialised in possessing an upright stem on which the little leaves are borne. These are arranged in three rows. In the leafy liverworts the stem is generally creeping, and though it may be so in some of the mosses, in the majority of cases it is erect. It is rooted to the ground by delicate branching filaments, which represent the root-system of the higher plants, and are called rhizoids. They are seen springing from the base of the stem in fig. 8, *b*.

The leaves vary a good deal in shape in different kinds of mosses, but are usually of very delicate texture, mostly consisting of a single layer of chlorophyll-containing cells, so that they are of green colour. They are not well protected against a dry atmosphere, as the cells have permeable walls and lose water readily by evaporation; hence most mosses live in damp, shady places. The permeability of the cell-walls, however, though a disadvantage to the plant in dry weather, enables the leaves to absorb water readily when they are wetted by dew or rain. There are very few other land plants which can absorb water through their leaves, as these are usually covered with an impervious substance called cuticle. The so-called filmy-ferns, however, many of which closely resemble mosses, and which grow in similar situations, have also leaves with permeable cell-walls, and absorb water through them. Some mosses, like the Hair-moss, which grow in dry positions have leaves of a harder texture, and the more delicate parts of the leaf are protected against loss of water by the edges of the leaf rolling over the central more delicate portion during dry weather. The reproductive organs of mosses are generally borne at the top of the stem. As in the case of the liverworts, they consist of archegonia containing the egg-cells and so-called antheridia containing the male reproductive cells or antherozoids. Both are microscopic in size and are concealed among the leaves borne at the top of the stem and protected by them. In the

case of the stems bearing the antheridia, the leaves are often peculiarly clustered together almost like a little, slightly concave green flower. When a drop of rain or dew falls on these the antheridia open and the numerous antherozoids will swim about in the drop of water. In the latter they reach the tips of adjoining stems of the moss-cushion and fertilise the egg-cells contained in the archegonia. As in the liverworts, the fertilised egg-cells grow up into spore capsules which may thus be seen attached to the top of the stem by a slender stalk, either completely erect or bent over near the tip. The spore-capsule of the mosses is much more elaborate than that of the liverworts and may be of very varying structure. The mosses indeed are classified largely according to the structure of the capsule. In the young condition the latter is covered by a cap (see fig. 8), which represents the top of the archegonium carried up by the growing capsule. At the top of the latter a little round lid can be noticed which breaks away when the capsule or spore-case is ripe, and then we see an opening guarded by a ring of teeth, four, eight, or sixteen in number. These are exceedingly sensitive to differences of moisture—hygroscopic, as we call it. In dry weather they bend outwards and allow the spores to escape, while in damp weather they contract over the opening so that no spores can fall out. The spores, therefore, are intended for dispersal through the dry air, and when the capsule on its delicate stalk is shaken by the winds the spores are carried

away and so distribute the moss into new regions. You will find many of the mosses fruiting in the early part of the year, and this enables the spores to germinate in the summer months when the weather is favourable for the growth of these small plants. The spores, unlike the seeds of Flowering Plants, do not generally pass through a period of rest. The germination of the spores brings us to a very interesting feature in the life-history of mosses. For the spore does not grow out at once into a new moss plant. It gives rise to a delicate growth consisting of branching green filaments closely resembling a small green Alga or primitive water-weed. In some cases a delicate thallus or frond is produced like that of a young liverwort. It is only later on when this youthful growth, or protonema as it is called, has extended over the soil that little buds arise on it which grow up into leafy shoots. If these are numerous, as is generally the case, we get a little cushion of leafy moss plants, which is the usual method of growth. Let us consider a little this juvenile stage or protonema, for it is full of interest. In the early stages of the life-history of many plants and animals we come across simple and primitive stages, which we now generally consider to be an indication of the more primitive ancestry of the plant or animal concerned. It is generally held that an organism repeats in its development some of the stages through which its ancestors passed in their evolution. So, for instance, the tadpole stage of the frog reminds us of the fish-like

predecessors of the amphibia. This theory has been called the "recapitulation theory," that is to say, the organisms are believed to recapitulate or repeat their ancestral history. In the case of the mosses, the simple condition of the protonema is taken to indicate that the ancestors of the mosses were filamentous or thalloid and not differentiated into stems and leaves. Possibly some were like simple liverworts, which we may, therefore, regard as the more primitive group of moss-like plants.

Before concluding this account of mosses, something must be said about a very special and peculiar form, the so-called Bog-moss or Turf-moss (Sphagnum). I have no doubt it is familiar to most people who have walked over moorlands or mountains where it so frequently forms large spongy cushions full of water in wet weather, and dry and springy during summer drought. Its structure is very different from that of other mosses. Its stem is covered with a layer of empty cells sometimes flask-shaped, which suck up water very rapidly and often draw it above the level of the surrounding soil. In the leaf, too, half the cells are of this nature, so that it can suck up water very much as blotting-paper does. How much it can hold you can see by squeezing out a handful. This bog-moss rapidly makes its appearance in hollows of the soil in which water lodges, and once it has started it may cover large areas. For as it can suck up water to its leaves it is not limited to the damp hollow in which it starts its growth, but can

extend and spread over the surrounding soil. In many places on the Continent it is found to cover many square miles and is still extending. Where it has been growing for a considerable time the lower parts of the plant will be found to have died away, and beneath the plant there may be extensive layers of peat formed from its remains. Indeed it is one of the main peat-forming plants, though not the only one, for the bog-cotton or cotton-grass can also be responsible for the formation of peat. Many of you may be familiar with the peat which covers the top of the Pennine Hills, but in other places, too, and at lower levels it is formed in great quantity, the peat being cut and dried for turfs, as we call the square blocks of peat or turf, which are so extensively used as fuel in many country places, particularly in Scotland and Ireland. It is not uncommon to find, where peat has accumulated to a great depth, that when sections are cut through it, the remains of trees, even apparently whole forests, may have been buried by the peat. Such buried trees are quite common in peat bogs, and the black bog-oak of Ireland is, of course, well known. We may attribute the killing of the trees to the growth of the bog-moss or Sphagnum, for it is a well-established fact that in some parts of the Continent the bog-moss is even to-day eating its way into forest-land by covering the roots of the trees with a wet blanket of water-logged vegetable growth which kills the trees and later buries their dead trunks. There they remain em-

bedded, not decaying away, as the brown water of the peat bog contains a certain acid (humic acid) which is antiseptic and prevents that development of fungi and bacteria, usually so active in causing the decomposition of wood and other vegetable matter. The plant-remains thus preserved in the peat can tell us something of the past vegetation, and investigations have shown that right down at the bottom of the peat of English and Scotch peat bogs we come upon dwarf birches and willows such as are found now in the Arctic regions, and which represent the vegetation that covered the hills of Britain in those far back days, shortly after the Great Ice Age, during which the greater part of Britain was covered with extensive glaciers. But though the Sphagnum conquered this primeval arctic vegetation and later the forest-land, and has thus deprived us of much valuable wood and timber, we can at any rate use it in the form of peat as a fuel capable of producing a pleasant smouldering fire.

During the war Sphagnum was largely collected, dried, and used as a dressing for wounds, being soft and absorbent. Otherwise, the mosses are of little economic use to man. The only moss besides Sphagnum which has any definite use is the large Hair-moss or Polytrichum, which also grows in boggy ground but does not suck up water like the bog-moss. Its wiry stems, which may be as much as two feet in height, were used in the past to make small brooms, and are still so used in some parts of the country.

CHAPTER VI

FERNS AND THEIR LIFE-HISTORY

LIKE the Mosses dealt with in the previous chapter, Ferns are in the main shade-loving plants. We associate them generally with woodlands, though many forms like the bracken grow equally well on the open hillside. Ferns are seen at their best in tropical or semi-tropical forests, where some grow tall with tree-like stems, while numerous other forms grow in the forks of branches or attached to the trunks of trees. These latter are not parasitic, that is, they do not take any nourishment out of the trees on which they grow, but are merely lifted above the ground so as not to be too much overshadowed by the rank and prolific vegetation of the forest. Such plants are called epiphytes, which means growing upon other plants. In this country we have only one epiphytic fern, the Common Polypody, which may grow on walls or between stones, but is also frequently found on moss-covered stems and on the branches of trees. Of tree-ferns we have none, for tree-ferns cannot resist cold weather such as we have in this country in winter, as they have no protective bark nor special winter buds such as our woodland

trees possess and which are a protection against frosts. Our ferns, therefore, have their stems underground or close above the ground, where they are sheltered by the dead leaves during the winter. The top of the stem is not covered by bud scales as in the winter buds of trees, but the young fronds for next year's growth are rolled up in crozier-like manner so that the tip which is the tender and growing part of the leaf is well protected, while the base of the leaf-stalk, the oldest and hardest part of the leaf, is the only exposed portion, and it is covered with numerous chaffy scales which give it sufficient protection. These scales are readily seen in the winter condition of the fern plant, when the young coiled-in leaves occupy the top of the somewhat thick stem. They can be seen best if you examine a frond in spring, when it is unfolding and when the tip is still coiled up in its characteristic manner. The frond forms what we call a compound leaf, consisting of many leaflets or pinnæ attached to the rachis, which corresponds to the midrib. Each leaflet may in some ferns be further divided into secondary leaflets or pinnules. It is usual for large leaves such as those of most ferns to be divided up into leaflets, as large leaves are less likely to be injured by strong winds when so divided. In the Harts-tongue fern (*Scolopendrium*), which has a comparatively small and strap-shaped frond, the latter is simple and undivided. The large size of fern fronds is connected with their shade-loving habit, for in the shade, the light

being less intense, a plant requires larger leaves so as to be able to absorb the amount of light necessary for its nutrition. The large size of the leaf, as compared with that of a moss, has been rendered possible because the ferns possess a better structure for absorbing water and food material than the delicate absorptive hairs or rhizoids of the mosses. In the group of ferns we find the plants have developed a root, or rather many roots, which can penetrate the soil to a considerable depth and are very efficient as absorptive organs. Mosses, though they have stems and leaves, have no real roots but only delicate rhizoids, and hence their size is more limited. Abundant absorption is, however, not the only need of the plant. The substances absorbed by the root, water and mineral salts in solution, must be conducted to the frond and to its finest ramifications. To do this efficiently in a large plant special channels for conduction are needed, and these are provided by the so-called vascular bundles of the plant, which have wide water-conducting cells with lignified walls. The ferns, indeed, are the most primitive group of plants which possess a true vascular system.

The Bracken is rather a specialised type of fern with a thin underground root-stock or rhizome, from which large and branching fronds arise at intervals. These fronds pierce their way upwards through the ground, the frond being bent downwards so as not to be injured during the upward growth, very much in the same way as seedlings draw their seed leaves

or the plumule out of the soil. Protected underground against severe cold and also against drought, and uninjured by any bush fire, the bracken is one of the hardiest and most widely distributed of ferns, occurring practically in almost every part of the world. It can also modify its frond in size and texture so as to adapt itself to a shady or to a sunny situation and to a warm or a cold climate. A variety known as *Pteridium esculentum* formed at one time an important food plant of the Maoris in New Zealand.

Another very specialised group of ferns, to which I have alluded in the last chapter, is that of the so-called Filmy Ferns, most of which are small plants. They have very delicate moss-like leaves, which are not covered by an impervious outer layer or cuticle, so that they would be in danger of losing too much water by evaporation unless they lived in very moist situations. Our most common British form, Hymenophyllum, grows on rocks near waterfalls, where it is constantly moistened by the spray, or in narrow clefts of rock and deep gullies in which the air remains cool and damp. This filmy fern can stand a great amount of cold, and may be frozen over in the winter but revives again in spring. Since the leaves of filmy ferns have permeable cell-walls, these ferns can take up water through their leaves and hence their roots tend to become rudimentary. They are of more use in fixing the plant to the rocks on which it grows than in absorbing water.

Let us now consider the life-history of the fern, for it is of particular interest. You know, of course, that it does not bear flowers. Instead we find on the under-surface of the fronds numerous little spore cases; these are arranged in groups called a sori.

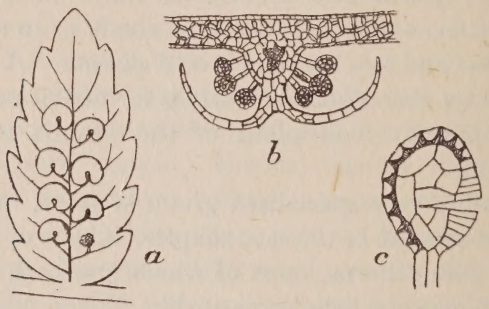

FIG. 9.—*a*, pinnule of the frond of the Shield Fern showing the sori covered in by their kidney-shaped indusium. In the case of the lowest sorus the covering has been omitted so as to show the cluster of spore cases; *b*, section taken through a sorus so as to show the spore cases or sporangia covered in by the indusium; *c*, enlarged view of spore case showing the crest-like annulus of thick-walled cells, which by contraction have caused the splitting of the sporangium.

Sometimes the latter are arranged in little round clusters as in the Common Polypody, or in lines along the lateral veins as in the Harts-tongue fern. In other cases, as in the Shield Fern, of which a leaflet is represented in fig. 9, *a*, they are covered in by a small kidney-shaped shield or indusium, and are also connected to one of the lateral veins. Fig. 9, *b* represents a diagrammatic section through such a leaflet just where it bears a sorus. The upper portion

represents the section of the leaf, and on its underside is seen a round projection to which the spore cases are attached. These are covered in by the indusium which stretches over them like an umbrella. The spore cases have a narrow stalk and contain numerous spores. In fig. 9, *c* the spore case is drawn on an enlarged scale so as to show the crest or annulus, which is composed of thicker cells and which, when the spore case is ripe and begins to get dry, contract, and thereby cause the spore case to split open and the spores are shot out. The spores are therefore shed in dry weather, and no harm comes to them since they are surrounded by a hard and impervious coat or cell-wall. They are very minute, much smaller than the smallest seeds, as they consist only of a single cell, and are readily carried even by slight currents of air. If in the late summer or autumn you shake a mature fern frond over a sheet of white paper, you can see these minute brown specks, and if you like you can collect and germinate them. In nature they begin to grow as soon as they reach a suitable damp place, in the crack of a wall or rock or on moist soil in a shady hedgerow. If you want to grow them yourselves you will find it a good plan to moisten a small plant pot and invert it, that is, place it with the wide end downwards on a plate covered with water and sprinkle the spores over the top and sides of the pot. Then cover the pot with a bell-jar or glass jam-jar. Another method is to grow them on porous and damp soil in

a pot, keeping it covered over with a piece of glass. The disadvantage of this method is that often other plants come up in the soil from seeds or spores contained in it, while in the former method you get a more or less pure culture of the fern. The reason why we can get the fern spores to grow with practically no soil is because the spores do not give rise at once to a new fern plant, but develop into a minute and delicate green growth which shows no stem and leaves, but looks like a little heart-shaped liverwort. This very delicate little structure is called the prothallus of the fern since it is thalloid, that is, not segmented into stem and leaves, and precedes the fern plant proper. It is attached to the soil or other substratum by delicate hair-like rhizoids similar to those of a liverwort. These are indicated at the base, *i.e.* the pointed end of the prothallus in fig. 10. We may, indeed, regard this stage in the life-history of the fern as its repetition or recapitulation of an ancestral condition, a stage in the evolution before the fern had developed into large leafy plants with a vascular system. It is another instance of a plant repeating in its development a stage of its evolutionary history.

The prothallus has no vascular system, as this is not required for so small a growth, the prothallus being rarely larger than a threepenny-piece. It is also composed of very delicate and unprotected cells, hence it can only exist in very moist conditions. No doubt many fern spores germinate in places

which are too dry for the prothallus to live, and probably a large number of these young embryonic plants die away. Hence the fern plant requires to produce a very large number of spores, and a single frond will bear tens of thousands of these minute

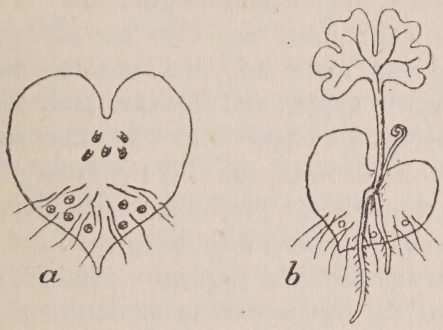

FIG. 10.—*a*, prothallus of Fern seen from the under-surface, showing archegonia at the upper and antheridia near the basal-pointed end. The absorbing hairs or rhizoids are seen around the antheridia; *b*, an older prothallus after fertilisation of one of the egg-cells of one of the archegonia. The young fern plant has developed from the egg-cell and shows two fronds, the younger one still rolled up, also two roots bearing root hairs.

bodies. When the prothallus has developed to its full extent, and this as I have said will only be a quarter or half an inch in diameter, it produces its reproductive organs on its under-surface. These are of two kinds (see fig. 10, *a*). The so-called archegonia, which are near the heart-shaped end, contain the egg-cells, and the antheridia, which are small globular bodies borne among the rhizoids near the pointed end of the prothallus, contain numerous

microscopic ciliated cells called antherozoids which can swim about in water when they are liberated from the antheridium. The latter opens in wet weather or whenever there is sufficient water present to enable the antherozoids to swim about. This they do vigorously, but not without guidance. It has been found by experiment that they are attracted by a vegetable acid, malic acid, the substance that gives the tartness to apples, and this same acid is secreted by the archegonia of the ferns when they open. So the antherozoids swim towards the archegonia, and entering through the projecting neck they fuse, or rather one of them fuses with the egg-cell and fertilises it. From the fertilised egg-cell a young fern plant grows up, the counterpart in miniature of the fern plant on which the spores were produced. Such a small fern plant is represented in fig. 10, *b*, attached to the prothallus. You will see that it has a downward growing root and a couple of fronds, the older one showing a bifurcation or forking, which is characteristic of the first few leaves, the second leaf shows the crozier-like rolling in of the leaf tip. Such young plants may often be seen in the cracks of rocks in damp places. The young plant now requires soil for its growth, and after a few years it will be large enough to begin producing spores. Thus the life-cycle of the fern has two independent stages, or generations as we call them, the smaller one the prothallus, comparatively temporary, and finishing its existence when it has produced a new fern plant.

Then it dies down, its function having been performed, while the fern plant proper goes on growing for many years, being indeed what we call a perennial plant.

This curious alternation in the life-history of the fern of the small prothallus and the large fern plant proper is called an "alternation of generations," for each of the stages is a generation complete in itself, since each finishes with the development or formation of reproductive cells—the archegonia and antheridia on the prothallus, and the spore-cases containing spores on the fronds of the fern plant.

Let us now consider the past history of ferns. Fern plants have existed for a very long period of time. In one of the oldest geological formations in which we have plant remains preserved—the Devonian rocks which are found both in Devonshire and in the north of Scotland—there are many remains of fossil ferns, some simpler than any existing at the present day, but others showing large and elaborate fronds like modern ferns. Ferns and fern-like plants were still more abundant in Carboniferous times, that is in that geological period in which large areas in Lancashire and Yorkshire were covered with great forests of a tropical or semi-tropical nature. The climate we can infer from the nature of the ferns, some of which are related to ferns which now exist only in tropical forests. But there were also many ferns belonging to a group which no longer exists nowadays. This is somewhat strange, as they are

the most highly specialised of fossil ferns, and we might, therefore, expect them to be the last to have arisen and most like the ferns of to-day. Their fronds are very like those of modern ferns, but instead of bearing spores like living ferns they bore seeds which are structures now found only on the so-called Flowering Plants. All flowerless plants of to-day bear spores ; but these ferns of the coal-measures, which were flowerless, had seeds at the ends of some of their leaflets, and seeds of comparatively large size, sometimes as large as hazel nuts, and of great complexity. It is only comparatively recently, *i.e.* since the beginning of the present century, that we have known this fact, and since then these highly specialised ferns have been placed in a special group called Seed-bearing Ferns or Pteridosperms. These seem to have died out in later geological times and none are known to exist nowadays. Thus the geological history of the ferns as well as the life-history of the ferns of to-day is full of interest, and this group of plants is well worthy of a close study.

CHAPTER VII

HORSETAILS AND CLUB-MOSSES

MANY of my readers may be familiar with the plant called Horsetail, though they may not have known its name. It grows in ponds and in the shallow parts of lakes, sometimes it is found in marshes. Some forms can grow in comparatively dry places, and may be seen on railway embankments or as very troublesome weeds in gardens, where they can make their way up through cinder paths and even through asphalt. They cause much trouble because their root-stock or rhizome, like that of most of the horsetails, runs underground at a great depth, and no pulling up of the stems will, therefore, eradicate the plant. The upright green stems of horsetails attract our attention, because they seem to have no leaves, though really they possess quite a number at each joint or node, as you will see from fig. 11, *a*, but the leaves are fused together at their base into a closed tube which grasps the joint above. It is comparatively easy to pull the joints apart, and then the little tube of fused leaves can be examined, each pointed tooth representing one of the leaves of the whorl or ring. A similar arrangement can be seen in the

side-shoots, but on these the leaves at each joint or node are less numerous, being sometimes not more than three, while on the main stem they may number from six to twenty.

The lateral or side-shoots seem to spring from below the sheath of leaves, as you will see in the figure, but as a matter of fact they arise in the first instance between the leaves and the main stem, in what is called the axil of the leaves, and then these lateral shoots bend outwards and break their way through the sheath to the exterior. From the fact that the leaves of the horsetails are so small we may assume that these plants are not essentially shade lovers ; for such plants, as we have seen in the case of the ferns, usually have large leaves, and from what is said above about the occurrence of the horsetails and from your own observations you will know that they grow mainly in open, sunny situations. How can the horsetails get along without leaves, which are the essential nutritive organs of a plant, absorbing as I have mentioned in an earlier chapter the sunlight, and thereby gaining the energy necessary for building up their organic food material ? Well, in the horsetails the slender green stem and the lateral shoots, in those forms which branch, undertake the work normally performed by leaves. The stem has plenty of the green chlorophyll and little pores by which the carbonic acid of the air can be taken in, and during the daytime the green stem and the lateral branches are busy building up sugar and starch for the plant.

The slender stems of these graceful plants, which in the case of the larger British forms may attain the height of three or more feet, are kept erect, as is the case also in the slender stems of grasses, by having their outer walls strengthened by crystals of a glass-like substance called silica, which is the hard constituent of glass. This tends to make the stems somewhat brittle when roughly handled, but in the living condition long and elastic fibres, which are also found in the stem, render it sufficiently pliable when exposed to wind or to waves in the case of aquatic forms. In the Common or Field Horsetail you can feel the rough surface of the stem due to the crystals, and this plant was formerly used for polishing the pewter plates and jugs. In former times large quantities of the Rough Equisetum were imported from Holland for this purpose under the name of Scouring Rush.

Internally the stems of the horsetails are hollow, and in addition to a central canal there are other hollow, air-containing passages which are concerned in conducting air taken in through the pores of the stem down to the root-stock, and to the roots, which are frequently growing either under water or in the water-logged soil of a marsh. In either case these submerged parts of the plant find it difficult or impossible to obtain the amount of air necessary for their respiration. For plants, like animals, require to breathe, and they do this in all the living parts of their body, including the roots. That is why fields

require to be drained, so that there should be air and not water between the particles of soil. When growing plants in pots, it is essential that the latter should be made of porous material and should be provided with a hole at the bottom through which the surplus water is drained off. If the roots of ordinary plants are grown in water-logged soil, that is to say in soil in which water instead of air fills the spaces between the particles of the soil, the roots die off and the plant can no longer grow. Water and marsh plants can, however, grow under these conditions, because they are provided with passages through which the air can be conducted from the aerial parts of the plants, the stem and leaves, down to the roots, which are underground or under water.

The reproductive organs of the horsetails are found at the top either of the ordinary green shoots of the plant, as represented in fig. 11, or they may be borne on special shoots which are sometimes of a brownish colour and die down after the spores have been shed. Horsetails, like ferns, belong to the spore-bearing or Flowerless Plants and not to the seed-bearing or Flowering Plants. The spore cases or sporangia are borne on specialised leaves which are set together in form of a cone (see fig. 11, *a*). These spore-bearing leaves, like the vegetative leaves, are arranged in rings or whorls around the stalk or axis of the cone. Each has a short stalk and a flattened, shield-shaped head more or less hexagonal or six-sided, as you will see from the outside of the cone, the stalk of the leaf

terminating in the middle of the six-sided plate. On the under or inner surface of the shield-shaped leaf, all round its stalk, the spore cases are found. Each case or sporangium contains a large number of spores, which are shed when the sporangia are ripe.

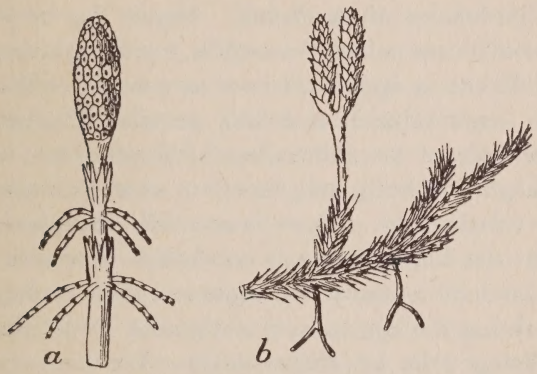

FIG. 11.—*a*, a fruiting stem of a Horsetail, showing the terminal cone made up of numerous hexagonal spore-producing leaves. The leaves of the stem inserted in rings are fused at their base into a sheath; *b*, terminal portion of a shoot of the Stagshorn Moss, one of the Club-mosses. The stem covered with narrow leaves branches by forking. It bears roots at intervals on its lower side and cones at the end of erect branches.

When these latter burst, the shield-shaped leaves becoming separated from those above and below by a slight elongation of the axis, the spores can then be blown out of the cone by the wind and are scattered far and wide. The spores are provided with curious, spirally-twisted processes, called elaters, which become entangled with each other, so that usually several spores will germinate together when

they get into a suitable moist situation. Like the fern-spores, those of the horsetails give rise on germinating to a small green growth or prothallus, so that we have the same kind of alternation of generations which is described in the previous chapter in the life-history of the ferns. Hence the horsetails are sometimes called Fern-allies, for though they are so different in appearance we may consider them in some ways related, and this peculiar feature, the occurrence of an alternation of generations in the life-history of both, may be taken as an indication of their relationship. There is one difference, however, for in the horsetails each prothallus produces only one kind of reproductive organs—either archegonia containing the egg-cells, or antheridia containing the fertilising cells or antherozoids. We can see the reason, therefore, why it is advantageous for the spores to germinate in proximity to one another; for this ensures that the motile antherozoids which are produced on one prothallus will be able to reach the archegonia not far away on another prothallus. The antherozoids swim about in the water into which they are liberated and make their way, as in the case of ferns, down the projecting neck of the archegonia to the egg-cells, which they fertilise. Then the egg-cell develops into a new horsetail plant with its curious jointed stem. Thus the cycle in the life-history is completed, and as in the ferns it includes two independent generations.

The same thing is seen in the life-history of the

Club-mosses, which are, therefore, also considered fern-allies, *i.e.* related to the ferns. Like the horsetails, they differ considerably in appearance and structure from the ferns. They have small, pointed leaves, which indicate that they are not essentially shade-loving plants. The British members of the group, at any rate, all grow on the open hillside and can frequently be seen on the dry slopes of the hills in the Lake District, Wales, and in Scotland. One of them is probably familiar to many readers as the Stagshorn Moss, producing long, branching stems which spread themselves over the close green turf of the hillside, and with their covering of narrow leaves are not unlike the stags' horns when they are still covered with velvety fur in the early summer (see fig. 11, *b*). The leaves are small and are not arranged in whorls at long intervals as in the horsetails, but are set spirally round the stem and close together. In the Alpine Club-moss, which one finds higher up on our hills, the leaves are somewhat broader and more scaly and are pressed close against the stem. Then there is the Fir Club-moss, which grows erect with bifurcating stem and branches, and looks like a miniature Christmas-tree. These are the three most common British forms. Though we call them club-mosses they are in no way related to mosses, for they possess a well-developed vascular system as do ferns and horsetails, and which mosses do not possess. These specialised water-conducting channels enable the plants to grow to a great length. One can often

find plants of the stagshorn moss extending to six or more feet in length. The stem has no main root, but is fixed to the ground at intervals, generally near the bifurcations, by roots which have a very characteristic habit of branching by repeated forking or bifurcation, very much as the stem does, and as is indicated in fig. 11, *b*. The reproductive organs are produced in cones. These are found at the end of little upright branches on the lower part of which the leaves are less crowded, so that they appear comparatively bare. The cones are borne either singly or more commonly in pairs, as you will see in the figure, and are covered with comparatively broad, overlapping leaves. Each leaf bears a single spore-case or sporangium on its upper surface. When the spore-case is ripe it opens in dry weather by a contraction of its walls and a cloud of small spores will be liberated, as you can see if you shake the cone or when the wind passes over them. The yellow spores are very dry and powdery and were formerly used for coating pills. They contain a good deal of oily material and when shaken over a flame burn with a sudden flare, for which reason they were at one time used to produce a flashlight in theatricals, because the flame they produced, though bright, is of very short duration and will not easily set fire to anything.

The spores when they germinate do not give rise directly to a new leafy plant, but, as I mentioned before, like the spores of ferns and of horsetails,

produce a prothallus. This, however, in the case of the British club-mosses is developed underground, probably because the open hillside is too dry for so delicate a structure as a prothallus. These underground prothalli of the club-mosses are of curious shape when compared with those of the ferns. They are small and top-shaped in some forms, or more elongate, and bear both archegonia and antheridia. The antherozoids produced in the latter fertilise the egg-cells contained on the archegonia and from the fertilised egg-cell the young club-moss is produced, thus completing the life-cycle. While our British club-mosses are terrestrial forms of low growth and are usually found on the open hillside, in the tropics they often occur in damp and shady forests, and there they do not necessarily grow in the soil, but may be found like some of the tropical ferns growing in the forks of trees or on their branches, in which case we speak of them as epiphytes. Club-mosses as well as ferns have been able to adopt this mode of life, as their very minute spores can readily be carried up into the branches of the trees. They can, however, only grow epiphytically where, as in the tropical forest, the air is moist and where there is no danger of exposure to frost.

Now let us consider for a little the past history of these two interesting groups of plants, the horsetails and the club-mosses. At the present time they are represented by herbaceous, *i.e.* non-woody types, generally not more than 2 or 3 feet in height. But

if we examine the fossil representatives of the horse-tails and club-mosses we find that in Carboniferous times, probably some fifty million years ago, they were of tree-like size and they represented the bulk of the vegetation of those vast swamp-forests which covered thousands of square miles in Britain, the north of France, Belgium, and Westphalia, and the fossilised remains of which we know as coal. Among these giant horsetails and club-mosses grew also the seed-bearing ferns which I mentioned in the last chapter. These were, however, of much smaller stature. We know that the coal-measure forests were of swampy nature, not only by the remains of fishes which are associated with the plant remains, but also because the internal structure of these plants reveals numerous and well-developed air passages, such as we find in aquatic and marsh plants of to-day, and which I described above in the case of the horse-tails. The fossil horsetails are called Calamites, and they show very much the same arrangement and structure of the vegetative organs as do the horse-tails of to-day, but they had thick, woody stems and rather more complicated cones. The carboniferous club-mosses were called Lepidodendra. They had thick, woody stems, often a hundred feet in height, which branched by repeated forking as do those of the club-mosses of to-day. In many of our museums, specimens of them and also of the massive branching root-system will give you a good idea of the size of the Lepidodendra. Their internal structure does not

agree very closely with that of living club-mosses, for these as I described above are generally found growing on dry hillsides, while the Lepidodendra were from their structure obviously marsh plants. The living plant most nearly related to the extinct Lepidodendra is a submerged aquatic plant found in our mountain tarns, the so-called Quillwort (*Isoëtes*), and its structure is in very close agreement with that of the Lepidodendra. Some marsh forms of Quillwort exist, one as near as Jersey, but they are all small plants not more than 6 to 9 inches in height. So the recent relatives of these trees of the coal-measure swamp-forests are very puny and degenerate descendants. In the struggle for existence size is evidently not the most important thing. Fitness to survive may be due to other factors, as I shall have occasion to mention in one of the later chapters. It is interesting to reflect that in another group of organisms we have the same striking difference between the size of the ancestors and that of their descendants. I refer to the giant reptiles of a somewhat later geological period. In what are called Mesozoic times reptiles forming the group of Dinosaurs attained the length of eighty or more feet, while the largest reptile of to-day, the crocodile, is only a quarter of the size. Here we find that the former reptiles of huge size have been superseded by smaller forms of greater agility, like the lizards, and probably endowed with other more useful characteristics, such as greater intelligence. In the case of plants where neither

agility nor intelligence exist we must assume that there were other reasons for the disappearance of the giant horsetails and club-mosses of the coal-measure period. Perhaps we shall learn some of the reasons from a consideration of the vegetation which superseded that of Carboniferous times.

CHAPTER VIII

CONIFERS AND THEIR ALLIES

In passing from Ferns to Conifers, we pass from the great division of primitive spore-bearing plants to that of plants which are reproduced by seeds. However small these seeds may be they are always much larger than the unicellular spores of ferns and mosses and very much larger than those of fungi.

The Pine, which is one of the best-known examples of a conifer, has cones which when ripe are made up of woody scales spirally arranged as shown on fig. 12, *a*. At first these scales are very closely set together, but when they are ripe the scales in drying become separated one from the other, and it can then be seen that each scale bears on its upper surface two oval seeds (see fig. 12, *c*), each of which is provided with a thin membranous wing by means of which the seed can be carried some distance away, when the wind shaking the branches causes the seeds to be shed. Each seed contains a little plant or embryo surrounded by a store of food material which is to nourish the young seedling during the early stages of germination. After having absorbed the food material, the seedling withdraws its seed leaves from

the seed and expands them above the ground. It will then be seen that these form a ring of six to eight leaves, which at once distinguishes the pine and its relatives, the spruce and the fir, from the majority of Flowering Plants, for these have only one or two seed leaves. The next leaves produced by the pine seedling are narrow, needle-shaped leaves, borne singly on the stem and arranged in a spiral. In the second year a change in the arrangement takes place, and the needles are borne in pairs or in groups of three or five on very short lateral branches called dwarf-shoots. Fig. 12, *b* shows the needles of the Scots Pine which are borne in pairs. This arrangement of the leaves continues in the mature plant and distinguishes the pine from other conifers, most of which like the spruce and the fir bear their leaves singly, while in the larch and the cedar the dwarf shoots bear as many as twenty or thirty leaves. Those of the larch are deciduous—that is, they last only for one vegetative season and are shed in the autumn. The larch is, therefore, leafless in the winter, but in the spring the dwarf shoots produce a new set of leaves. Hence the larch trees are clothed in spring with a foliage of tender green, very different from the dark green foliage of other conifers. For most of these are evergreens. This must not be taken to mean that the leaves last for ever, but that they remain on the trees for several, or, indeed, many seasons, so that the tree always has a mass of green leaves. The older ones are, however, shed

as time goes on, and in the case of the pine the whole dwarf shoot bearing the leaves drops off. The leaves of such evergreen trees are not only darker in colour but harder in texture than are deciduous leaves, for

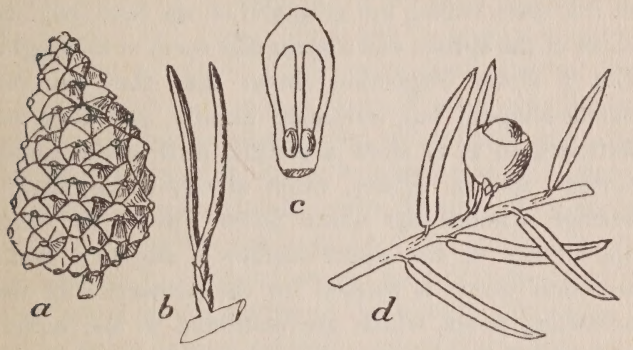

FIG. 12.—*a*, closed cone of Scots Pine showing arrangement of scales; *b*, dwarf shoot of Scots Pine bearing two needle-shaped green leaves surrounded at their base by a group of small scale leaves; *c*, a cone scale of the Pine showing on its upper surface two winged seeds; *d*, a fruiting branch of the Yew showing shape and arrangement of the leaves and the so-called "berry," consisting of a central seed covered in at the base by the fleshy aril or second seed-coat. In the mature "berry" the seed would be more completely covered in.

they have to last out during the adverse period of the winter months.

The leaves of the Spruce or Spruce Fir (*Picea*), as it is sometimes called, are needle-shaped and spiny like those of the Scots Pine (*Pinus sylvestris*), sometimes incorrectly called Scotch Fir, but are much shorter than the latter and, as stated above, arranged spirally round the branches. The Spruce is commonly used for Christmas-trees. It is not a native of

Britain though common on the Continent. It was, however, before the great Ice Age, a native of Britain, for its remains have been found in pre-glacial gravel beds. The leaves of the real Fir (*Abies*) or Silver Fir, as it is often called, are arranged on the branches like those of the spruce and appear like them at first sight. But a closer inspection shows that they are not needle-shaped, but terminate bluntly, and they are flattened so as to show a distinct dark green upper surface, and a lighter, often silvery-white, under-surface, whence the name Silver Fir. This white appearance of the under-surface is due to a waxy secretion which is formed for the protection of the breathing pores, which are restricted to the under-surface of the leaves. In almost all conifers the leaves are narrow even when not needle-shaped, and this type of leaf is very suitable for plants growing in very dry situations, such as are characteristic for the conifers, which love to grow on steep and exposed hillsides, as in the Alps, or on sandy soil. The Scots Pine grows by preference on sandy moorlands, while other pines, like the Cluster Pine, grow along the sandy wastes of the dunes, and are often planted in France along the coast for the purpose of reclaiming such wastes. These particular pines yield a considerable amount of turpentine, which is obtained by tapping the trees. The turpentine is secreted in the bark and wood and is contained in long, narrow passages called resin ducts, which run between the cells throughout the plant. Into these ducts both

oil of turpentine and resin are secreted—the latter, a hard and yellowish substance, being dissolved in the oil of turpentine. The purpose of this resinous secretion is to heal any wounds which may be caused by the breaking of branches or by animals gnawing the bark of the trees. Then the turpentine exudes, and being a volatile oil it evaporates, leaving the wound closed over with a layer of resin, which prevents both loss of water from the wound and also the penetration of the latter by wood-rotting bacteria and fungi. In tapping the trees for turpentine slight cuts are made into the wood, and the cutting has to be continually repeated as the flow of turpentine is interrupted by the caking of the wound with resin.

The leaves of most conifers contain resin ducts, and the turpentine no doubt renders them distasteful to certain animals and acts therefore as a deterrent. Besides, the hard and spiny leaves are not inviting to the larger herbivorous animals, though the leaves are readily devoured by many kinds of caterpillars.

The reproductive organs of the pine are borne near the ends of the branches. The male cones are small and yellowish in colour and are arranged in clusters of from twenty to fifty all round the young shoots. About the month of May they mature their pollen, which consists of minute yellow grains provided with two light wings, enabling the pollen to be readily carried by the wind. If a twig bearing ripe male cones is shaken, the yellow cloud of powder which is set free will give some idea of the enormous mass

of pollen which is produced by even a small cluster of cones, and one can imagine how much is produced by a whole tree, though probably no one can form an idea of how much would be produced by a whole forest of pines. These pollen grains are carried by the wind to the female cones, which are borne singly or in small numbers at the end of the youngest shoots. These cones are built up of small scales, on each of which two ovules or immature seeds are borne. The latter are pollinated by the pollen grains in May or June, but no further change takes place in them until the summer of the subsequent year when they begin to swell, and they ripen towards the end of the second year of their existence. During this second year they are green in colour, but towards the autumn the scales get brown and woody, and separate so as to liberate the seeds. In one species called the Bishop's Pine (*Pinus muricata*) which grows in California, the cones, which are 6 inches in length, do not open. They may remain for thirty or more years attached to the tree and enclose the seeds which retain their vitality and germinating power throughout that time. It is stated that the cones only shed their seeds when a forest fire has occurred and the outer part of the cone is thereby damaged. This would account for the fact that in forests of the Bishop's Pine all trees are found to be of about the same age, and one does not find trees of different ages as is usual where seeds are shed annually.

Not all conifers, however, form woody cones. In-

cluded in this group of plants are trees which though they agree with the conifers in having sharp, spiny leaves as well as in other characters of their vegetative organs, have very different kinds of fruits. The Juniper is one of these. Its leaves are needle-shaped like those of a pine, but borne in rings of three at each joint or node of the stem, the fruit consists of three fleshy leaves, which are fused together and surround three seeds which are thus enclosed in a berry. In the unripe condition the fruit is green, but when ripe it is bluish and has a sweet but somewhat turpentiny taste. The juniper berries are used in the manufacture of gin.

The Yew is another somewhat abnormal member of the conifers, for its fruit can hardly be called a cone, and the leaves are not needle-like. It is true they run to a sharp point, but they are not stiff like the leaves of the spruce, for example. Though narrow, they are flat and rather sickle-shaped in appearance, as can be seen from fig. 12, *d*. The fructification, which is often called a "berry," is really an oval seed which is surrounded by a red, fleshy covering of the nature of a seed-coat. This second seed-coat or aril as it is called attracts birds, which devour it with relish, but reject the seeds, and so aid in their dispersal. The aril is not poisonous, but the seeds and the foliage of the yew are very poisonous and are usually avoided by cattle, but horses have been known to be poisoned by browsing upon it. Thus while in other conifers the sharp needles and the

turpentine acts as a deterrent against herbivorous animals, the yew with more normal foliage relies upon poisonous substances for its protection. The Scots pine, the juniper, and the yew are the only British representatives of the group of conifers. The spruce and the fir though common are only cultivated in Britain, but native on the continent of Europe. The larch is a native of higher valleys in Switzerland, being generally found at an altitude of 6000 feet.

Let us now consider some of the more interesting of the American conifers. One of these is the Swamp Cypress (*Taxodium*) which grows in the great Dismal Swamp off the Mississippi and also in swamps along the coast of Florida. It is the only conifer which likes a wet place to grow in. Its leaves are narrow, but tender and not hard like those of the pine, and are shed every year like those of the larch, so that it is bare in winter. Growing as it does in swamps, its roots would have difficulty in getting the necessary air, so it sends up special breathing roots, which come above the water and take in air through small pores which cover their tips. These upright roots, which rise up round the base of the trunk and are called "knees," give the tree a very queer appearance. The Swamp Cypress occurs only in the southern portion of the United States, but in comparatively recent geological times it existed all over Europe; and the greater part of the Tertiary coal of Germany, "brown coal," as it is called, is due to the remains of the swamp forests of that period, consisting mainly

of swamp cypresses. Two other interesting American conifers which are restricted to the Pacific Coast are the so-called Big Trees of California. There are two allied species—the American Redwood (*Sequoia sempervirens*), which grows at comparatively low levels, and the Big Tree proper or Mammoth Tree (*Sequoia gigantea*), which grows 3000 feet above sea-level on the slopes of the Sierra Nevada. Both of these had formerly a wider distribution, and plants very closely resembling them have been found in a fossil condition in Britain and on the continent of Europe. We may consider them ancient and disappearing forms, and indeed there was so much danger of the Mammoth Trees becoming extinct if felled for timber, that the groves in which they grow have now been scheduled by the American Government as Nature Reserves, and not only may the trees not be felled, but no camp fires may be lit in these preserved areas. As their name indicates, the Mammoth Trees are the largest, if not the tallest, known trees. They may attain a height of 300 feet, and at their base may measure 16 feet across or about 50 feet in circumference. When young the trees grow rapidly as do most conifers, but when they have grown up so to speak, that is when they have become mature, they grow very slowly, but keep on growing, especially in girth, for many hundreds of years, and may reach an age of 1500 to 2000 years. We can tell this by counting the annual rings seen in a cross-section of the stem of a tree which has been cut down. For all

trees growing in a climate which has a distinct winter season gradually begin to decrease the size of their wood cells in the autumn, until they stop forming them in the winter and commence in the spring again to form large cells. This alternation causes the formation of the so-called annual rings.

Another very interesting tree allied to the conifers is the so-called Maidenhair Tree (*Ginkgo*), which is grown largely round the temples in China and Japan. It takes its name from the shape of the leaves, which are rather like the segments of the frond of the Maidenhair Fern. They are about the size of a poplar leaf, and have no proper tip but are indented at the apex, which is wider than the base. The leaf has no midrib but a bifurcating venation such as we find in many ferns. The seeds are fleshy and look like small green plums. Though it has been known for a long time, it was not certain until recently where this tree grew naturally, for it had only been found growing around the temples of China and Japan. It is now generally believed that its home is somewhere in China. It is probably also a disappearing tree, for it has already vanished from Britain and Europe generally, where it grew in Mesozoic times, its fossil remains being met with frequently in the Jurassic rocks of Yorkshire. It represents, therefore, probably one of the most ancient of the trees allied to the conifers ; for it is not usual now to include it among the conifers, though formerly it was placed in the same group as the yew.

There are other allies of the conifers which are of considerable interest in considering the origin of this group of plants. The Cycads, which resemble small palms, though they have no relationship with the latter, bear very large cones, and in this respect resemble the conifers ; but their vegetative character is very different. Firstly, they have a short and unbranched stem usually very thick, and they bear large and divided leaves often a yard in length. In some species, these leaves look very fern-like, and when we study their microscopic structure they are not unlike the seed-bearing ferns which, as stated, existed in the coal-measure forests. There is little doubt nowadays that the cycads developed from fern-like plants of previous ages and quite possibly the cycads later gave rise to the conifers, for the cycads are an older group of plants than the conifers and are found in large numbers in the middle Geological Period, the Mesozoic times. At that time they grew in Britain, but now they are chiefly confined to the southern hemisphere, and are common to South Africa and Australia, though a few are found in China and Japan, and others in the southern States of North America. They were at one time the dominant vegetation of the northern hemisphere, but their place has been taken by the conifers, which exist both in the southern and the northern hemispheres, and in the North cover vast areas, as in Russia, Scandinavia, and Canada, with immense forests.

CHAPTER IX

FLOWERING PLANTS AND THEIR ORIGIN

FLOWERING PLANTS really include the conifers which were dealt with in the preceding chapter, for the young cones are a kind of flower, though perhaps not what we usually understand by that term. For when we think of a flower, we picture to ourselves something with bright petals and perhaps an attractive scent as well. Such flowers we find among the plants we call Angiosperms. That is rather a difficult word, which means closed-seeded plants, because in these plants the seeds are enclosed in what is called a seed-vessel such as the one represented in fig. 13, B. The poppy-head, or the pod of a pea, are examples of what we call seed-vessels. Plants with such seed-vessels differ in this respect from the conifers, for the seeds of the latter are not enclosed, but are borne, as stated in the previous chapter, on the upper surface of the woody scales which make up the cone (see fig. 12, *c*). Such plants are called Gymnosperms, another long word which means naked-seeded plants, as the seeds are borne openly on the scales of the cones. Gymnosperms and Angiosperms together make up the group of Flowering Plants, and it is

with the Angiosperms, which are by far the most numerous of the Flowering Plants, that this chapter deals. The Angiosperms must be considered the more specialised group of Flowering Plants, for the closed seed-vessels they possess are formed from open seed-bearing leaves, which during their later development become closed. But in other respects, too, the Angiosperms are more highly developed, and, therefore, less primitive than the conifers. Their flowers are, as I have said, usually brightly coloured owing to the development of conspicuous floral leaves which we call petals (marked *p* in fig. 13). These are not usually the outermost leaves of the flower, for they are tender and delicate and require protection in the bud condition. This protection is afforded by an outer group of tougher leaves, usually green, which are called the sepals (marked *s* in fig. 13, A). The sepals are generally smaller than the petals, so that the latter are often somewhat crumpled or folded up in the bud. When the latter opens the sepals may drop away, having served their purpose of protecting the flower-bud. This happens in the case of the poppy, so that the large red petals, when they have become expanded, seem to form the outermost leaves of the flower. In other flowers the sepals and petals may both be brightly coloured, as is the case in the tulip. Here the outer ring of three leaves which are green in the bud correspond to the sepals, but later they become coloured like petals.

There are, of course, some flowers which are not

brightly coloured, but in all cases where they are large and contrast markedly with the green foliage the colour is intended to render them conspicuous to insects which in visiting the flowers effect the pollination and ultimately the fertilisation of the seeds.

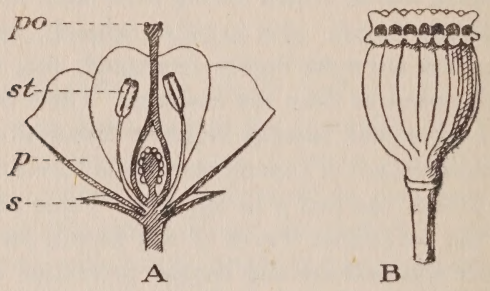

FIG. 13.—A, diagrammatic section through a typical flower showing the arrangement of its various parts; *s*=sepals, *p*=petal, *st*=stamen, *po*=pollen grains. The latter have been deposited on the stigma. Later a pollen-tube will grow down through the tall style to the hollow ovary in which the numerous ovules are shown. These will develop into the seeds; B, capsule or seed-vessel of the Poppy. The seeds when ripe are shaken out through the small holes seen round the top of the capsule.

Where the flowers are not conspicuously coloured, as for instance in the mignonette, they may be provided with a strong scent which will enable insects to find them even at night-time. The insects, of course, visit the flowers for the sake of the honey or nectar which the flowers secrete, sometimes at the base of the petals, sometimes in special pouches or spurs as in the flowers of the violet and pansy. The shape and arrangement of the petals is most wonder-

fully varied and always adapted to the special insects which visit the flower, and they are often marked with distinct lines or rows of coloured spots, called honey guides, which direct the insect to the place where the nectar is secreted. It is quite impossible for me to describe the many and various ways in which flowers are adapted to the visits of insects, but you will find descriptions of some of the more striking examples in most textbooks.

Now let us see what are the parts of the flower that lie within the petals. First we come to the stamens. These, as you will see from fig. 13 where they are marked *st*, are composed of a slender filament which bears at its end a thicker portion which we call an anther, in which are four pollen-sacs, only two being visible in a side view such as is represented in the illustration. The pollen-sacs open when the pollen is ripe, either by longitudinal slits or by pores at the top of the anther, and then the yellow flower-dust or pollen is liberated, as you can easily see by putting your finger against the stamens of a lily The pollen grains being sticky will adhere to your finger, and will do so equally to the head or body of an insect which visits the flower and may touch the stamen. The insect in passing on to another flower will thus carry away some of the pollen, and will be very likely to rub it off against the little knob which protrudes on a long stalk from the seed-vessel. I have indicated some pollen grains, marked *po*, on the top of this knob in the drawing. The knob is

called the stigma. It is not always rounded as shown in my drawing, but sometimes divided into two or more delicate tips, and when the flower is mature is often covered with hairs or with a secretion, so that the pollen grains adhere readily to it. This transferring of pollen on to the stigma of a flower we call pollination, and it is followed by the fertilisation of the flower. For the pollen germinates on the stigma, and a long, slender tube, the pollen-tube, grows down through the style, which is the name given to the stalk carrying the stigma, right into the seed-vessel, where the pollen-tube enters one of the ovules or immature seeds, and the living substance of the pollen grain unites with a minute egg-cell contained in the ovule. This is what we call the fertilisation of the flower, the result of which is that the ovule develops an embryonic plant, which, growing inside the ovule, causes the latter to increase in size and ultimately to form the ripe seed.

Thus we see that both the pollen and the ovule or immature seed are necessary for the production of a new plant. Seeing that they are generally both found within the same flower, as I have shown in the drawing, you may wonder why insects are necessary for effecting the pollination, and why the anthers bearing the pollen-sacs do not come in contact with the stigma which is often close to them, though in my drawing and in many plants the stigma is well out of reach of the anthers. Well, it is a remarkable fact that we find the pollen of a flower is frequently

not yet ripe when the stigma is ready to be pollinated, or else the pollen ripens before the stigma is ready to receive the pollen, so that self-pollination is impossible or nearly so. That would seem to indicate that cross-pollination may be more helpful in securing fertilisation than self-pollination. This is actually the case, for Darwin, who studied plants very closely from this point of view and made many careful experiments, found that cross-pollination produced a larger number of seeds than self-pollination, and also that the seeds produced by cross pollination gave rise to more vigorous seedlings than seeds resulting from self-pollination. It is obvious, therefore, that it is an advantage to plants to have their flowers cross-pollinated, and hence the various devices to cause insects to visit the flowers and to carry pollen from flower to flower.

But other methods may be adopted to effect the same results. In the tropics small humming-birds with long beaks are attracted to flowers, about which they hover, sucking the honey from them, but at the same time getting some pollen stuck to their beaks or heads and cross-pollinating the next flower they visit. The wind, too, can effect cross-pollination. Most of our catkin-bearing trees, and most grasses, both of which plants have comparatively inconspicuous flowers, which are not visited by insects, are wind pollinated. Their flowers are either borne on very slender, upright stems, as in the case of the grasses, which are very easily shaken by the wind,

or the plants have pendant catkins from which the pollen is easily shaken, as you can see by shaking the hazel catkins, for example. This dry, powdery pollen is readily carried by the wind, as it is in the case of the conifers, and when it reaches the stigma cross-pollination is effected.

We must now see what happens when the ovules or young seeds after being fertilised begin to set. At first, as I mentioned before, they enlarge, keeping pace with the developing embryo within them, and thus they give it room to grow. The seed-vessel also enlarges, keeping pace with the seeds within it. When the seeds are ripe their seed-coat has become hard and protective, so that they are able to resist both drought and cold for a considerable time. For how long it is difficult to say, and the time depends both on the nature of the seed and the conditions under which it is kept. When dry, seeds keep much better than when damp. You may perhaps have heard or read that grains of wheat taken from Egyptian tombs—" mummy wheat," as it has been called—has been found able to germinate. That would mean that such seeds had retained their vitality for several thousands of years. But this is not really the case. We know of no instance of wheat actually taken from such a tomb which has germinated. The only accurate records we have, show that certain seeds, mainly those of leguminous plants, *i.e.* belonging to the Pea Family, which have a very resistant seed-coat, have germinated a hundred

or a hundred and fifty years after they were gathered. Still even this shows that some seeds can remain in a state of suspended animation for a very long time, and that is wonderful enough.

We have still to consider how seeds are sown in nature. It is important for the continued existence of a species that the seeds should be carried to some distance from the parent plant. For if they germinate too near to their parent they might be overshadowed and not be able to grow, and if a large number of seedlings were crowded together close to where the seeds matured probably only a few would survive. Possibly those who have done a little gardening will have experienced the bad effect of sowing their seeds too closely together. They germinated, no doubt, quite readily, but they would not grow into healthy plants, and probably very few would arrive at maturity. The stronger ones would overshadow the more weakly, and this would cause the latter to die off altogether. Gardening experience has taught us that seedlings, even when carefully sown, require to be "thinned out"—that is to say, we must pull up a great many so that the remaining ones may have room to develop properly and grow into robust plants. In nature, therefore, plants have adopted various methods to secure the proper scattering of their seeds. Sometimes the seed-vessel splits very suddenly and the seeds are shot out to a considerable distance. On a hot summer's day, if you are sitting close to a gorse bush, you may hear little cracking noises as

the ripe pods burst and shoot out the seeds. The same happens in the broom and in many other pod-bearing plants. In other cases the seed-vessel is placed on a long and slender stalk, as is for instance the seed capsule of the poppy, and then when swayed by the wind the seeds are shaken out through little holes at the top of the seed-vessel (see fig. 13, B). In some instances the seed-vessel and in other cases the individual seeds are provided with delicate wings or feathery plumes, and may then be carried great distances by the wind. On bare patches of ground plants with such seeds are likely to be the first to spring up, for such plants are great colonisers of new ground. Thistles, groundsel, willow-herb, are among these adventurers, and the first two are characteristic as troublesome weeds, partly owing to their great fertility and partly to the fact that their seeds are so readily carried by the wind.

Other plants use animals to carry their fruits or seeds. Burrs and cleavers, for instance, will stick to sheep or other woolly or furry animals and so are spread about. All fleshy fruits or seeds are intended to be dispersed by fruit-eating animals, mainly birds in this country. For this reason fleshy fruits are usually brightly coloured and contain sugar and other attractive food substances. A few seeds have little food bodies attached to them, which are sought after and eaten by ants. The latter often carry the seeds to their nests and leave many by the wayside in so doing. The broom and gorse have orange-coloured

food bodies attached to them, and those of the sweet violet and the greater celandine, which are similarly provided with white food bodies, are also distributed by ants.

When the seeds arrive in a suitable place for germination, they are washed by rain into the cracks of soil, or they may become covered by wind-borne particles of dust or by worm castings, and they remain dormant until the conditions of the climate are suitable for germination. Then when they have sufficient water and warmth they germinate. The root of the embryo plant grows out through a small hole in the seed-coat and grows down into the soil in search of water and food material. In the meanwhile the store of food material in the seed is being used up by the growing embryo, which soon sends its young shoot and green leaves above the ground, and then the seedling begins to nourish itself by their aid. From what has been said above it will be clear that, compared with the plants dealt with in the previous chapters, the Flowering Plants are by far the most complicated in their structure, particularly in that of their reproductive organs and their adaptations to insects and other animals. We must therefore regard them as the most highly organised group of plants. They made their appearance comparatively late in the history of the earth. None of them existed in the Carboniferous Age, that period of the earth's history when, as I mentioned in one of the earlier chapters, Lancashire was covered with

great swamp-forests of horsetails, club-mosses, and ferns. None of them existed in the subsequent Jurassic Period, when the cycads, which I mentioned in the last chapter, the maidenhair trees, and some of the conifers were growing in Britain. The earliest fossil remains of Angiosperms, the group with which I have been dealing in this chapter, appeared in what we call Cretaceous times, in days when the great deposits which form the chalk downs were being laid down. But the majority of the Flowering Plants such as we meet with to-day are of much more recent origin and do not appear as fossils until the Tertiary Period, which is comparatively recent in the history of the earth. What group of plants they sprang from is still very uncertain. Some botanists hold that the Angiosperms—*i.e.* the closed-seeded plants—sprang from a group of cycad-like plants, which had a comparatively complicated arrangement of reproductive leaves that might be compared to a flower at an early stage of evolution. Others think that the Angiosperms have arisen from another group of Gymnosperms, not the conifers proper, but allied to them, which also have certain features in common with the Angiosperms. For the time being, therefore, we cannot give any definite answer to the question as to the origin of the Angiosperms, the group of plants which makes up the bulk of the conspicuous vegetation of to-day. The solution of this problem can only come after further close and careful investigation of fossil

plants of the Late Cretaceous and Early Tertiary deposits. Perhaps it is as well that there should be such an important scientific investigation left over for the younger generation to tackle and, let us hope, to solve.

CHAPTER X

THE EVOLUTION OF PLANTS

As I mentioned in the last chapter, the Flowering Plants, the most highly organised of all existing plants, are only found in a fossil condition in comparatively recent rocks (Secondary and Tertiary), while plants with a simpler organisation, like the ferns and their allies the horsetails and club-mosses, are found as fossils in much older deposits (Primary or Palæozoic). We may, therefore, infer that at that earlier period in the earth's history no Flowering Plants existed and that the vegetation consisted of the more primitive types. The farther back we go in the geological history of the earth the simpler the organisation of plants and animals becomes. As the simplest of existing plants are, as I mentioned in some of the earlier chapters, mainly aquatic like seaweeds, we have some reason for believing that the earliest plants which existed were aquatic forms, possibly resembling those microscopic motile organisms, Euglena and Chlamydomonas, which I described in the first chapter. Then probably some of them became fixed to rocks and developed into seaweed-like forms. Unfortunately these very primitive, and particularly the microscopic

forms, are far too delicate to have been preserved in a fossil condition, so that our record of the first plants that existed is not a satisfactory one and is not likely to become so. However, many of the brown seaweeds have a pretty tough body, and some fossil plants found in some of the most ancient plant-bearing rocks (Palæozoic) in Scotland and Canada are now generally believed to be possible relatives of the large brown seaweeds.

The next step in the evolution of plants, and it was a big step forward, was the adaptation of plants to a life on land. It is quite possible that a land habit may have been adopted by various aquatic plants, and this may possibly account for the variety of land plants which appear as fossils approximately in the same geological deposits. In all probability, however, they were comparatively small plants, and indeed the earliest of the known land plants which have been found in the Devonian rocks of Scotland and Norway are only between 3 and 9 inches in height. It has been suggested that some of their characters indicate that we have in them actually the transition from seaweeds to early land plants. They were either entirely leafless or possessed very rudimentary leaves. But simple though their outward structure shows them to have been, they possessed two characters, from which we can unhesitatingly say that they were land plants. In the first place, they possessed a vascular system, simple and rudimentary in some of the forms, it is true,

yet a feature characteristic of land plants. For these, if they grow to any size, require special conducting channels to transport the water from the soil to the aerial parts of the plant. Secondly, these primitive land plants of the Devonian period produced spores with hard cell-walls, evidently intended for distribution through the air. The spore-cases in which they were produced at the tip of some of their shoots resemble those of some of the simpler types of liverworts and mosses, rather than those of the ferns and their allies ; for in the latter the spore-cases are always borne on the leaves. The first land plants, therefore, of which we have well-preserved remains in the fossil condition, combine some of the characters of the liverworts and mosses with those of the ferns and their allies. This suggests, therefore, that both these groups of spore-bearing land plants may have had a common origin. It is very probable that the earliest land plants established themselves near the water, since they had an aquatic origin ; and even the tree-like horsetails and club-mosses, which are described in Chapter VII, though they had become gigantic compared to the first land plants, still grew in swamps or marshes. Indeed the living ferns and their allies are generally adapted to a moist situation, because they have retained characters which they have probably inherited from their aquatic ancestors. You will remember from the account of the life-history of the fern, that this group of plants has a delicate and temporary stage in its life-history—the prothallus

which produces motile reproductive cells called antherozoids. These escaping from the prothallus into the water swim about and make their way into the archegonia where they fertilise the egg-cells. The new fern plant cannot therefore arise without passing through a stage which, owing to the delicate nature of the prothallus and its motile reproductive cells, requires, at all events temporarily, a good deal of moisture.

The next move of the primitive land plants was to adapt themselves to drier conditions, and this was done by the development of a seed in the place of spores. Within the seed the tender prothallial stage could be sheltered and the young plant nursed during the earlier stages of development. Such seed-like structures we find commencing to be formed in some of the fossil club-mosses of the Carboniferous period, and still more completely developed in the seed-bearing ferns mentioned at the end of Chapter VI. The seed-bearing ferns undoubtedly gave rise to the cycads of the next geological period, the Secondary or Mesozoic Age, to plants which had many fern-like characters, including the very large and divided leaves, but which usually bore their seeds in a definite cone-like arrangement. We do not include these plants among the conifers, but they are generally considered to be the ancestors of the conifers. The latter, as I mentioned in an earlier chapter, have narrow, needle-shaped leaves, which lose very little water through their breathing pores or stomata into

the air, and so can grow in dry climates and also on sandy soil, which does not retain its moisture so readily as clay soil does.

One might have thought that with the development of the conifers which can grow in such very dry conditions, so that the greater part of the land was conquered and occupied by plants, the evolution of still higher forms would not have been necessary. But there was still one step farther to go in the way of protecting the prothallus and the embryonic plant. The seed surrounded by an integument or seed-coat as it exists in the conifers was good in its way as a protection of the delicate prothallus and embryo, but in the Angiosperms, which may be called the Flowering Plants proper, since they make up the bulk of that group of plants, the seeds which as we have seen are definitely protective structures, are themselves protected during their development against external influences, more particularly against drought, by being enclosed in a seed-vessel which later becomes the fruit. This advantage from one point of view might be a disadvantage from the point of view of the fertilisation, since the pollen grains can no longer be carried to the ovule or young seed as is possible in the conifers, where the ovules are borne on the upper surface of the cone scales. Therefore in the Angiosperms the pollen has had to adapt itself to the new conditions, and as I pointed out in the previous chapter it germinates on the top of the stigma and sends its pollen-tube down into the closed ovary and

right into the ovule, in which the microscopic egg-cell is then fertilised. All through the stages of growth and development of the ovule into the mature seed, the wall of the seed-vessel in which it is contained acts as its protective covering.

If then we take a retrospective view of the evolution of plants, considering the various stages in this development during the successive geological periods, we find that the story unfolds itself as a gradual adaptation of these plants to drier conditions of life. Beginning their existence as microscopic organisms probably in the sea, they developed into larger aquatic plants fixed to the rocks (seaweeds). Then some became adapted to a life on land, not far from the water's edge or from its influence (mosses and ferns). Lastly, with the seed-bearing habit, all land was open to them to conquer, and we find them now spread over the whole habitable surface of the earth. The earlier and simpler forms of existing seed-bearing plants, the Gymnosperms, were at first the dominant group, but now, though they still maintain their dominance in some regions, as in the great coniferous forests of the northern regions, in most places they have been superseded numerically by the Flowering Plants proper, the Angiosperms, which represent the most specialised and highly differentiated of plants.

Let us now consider the way in which this gradual evolution of more and more specialised plants may have come about. Was it a direct modification of

the plants by the drier conditions to which they spread or was there some other cause? There is no doubt that varying external conditions such as climate or surroundings may modify individual plants very considerably. But the question is still unsettled to what extent, if at all, such "acquired characters" are transmitted to the offspring. If they are transmitted, that is to say if the seedlings derived from the modified parent plant inherit this modification, then undoubtedly we may conceive the new types of vegetation to be directly produced by the action of external conditions upon the plants. That was the view of Lamarck, the great French naturalist, at the beginning of the nineteenth century. But Darwin in his *Origin of Species*, published in 1859, put forward another view, which has been more generally adopted. Darwin had observed that the numerous offspring of two plants or animals are never exactly alike, but show all sorts of variations in structure, often very slight variations, but still distinguishable to the practised eye. He had also realised that since the surface of the earth is already covered with vegetation, as far as the conditions are suitable for the growth of plants, there is no room for the very large number of offspring which will result from the numerous seeds. Many, indeed most, of the seedlings will therefore not arrive at maturity. Which will be the survivors? Evidently those which from their structure or vigour will be the "most fit to survive," *i.e.* the most suited to the conditions of life.

If, therefore, some peculiarity of structure renders one or more of the offspring more fit or suited to the conditions of life, those will be the survivors. This Darwin called " natural selection." If we apply this theory of natural selection, say, to the primitive water plants, which were possibly overcrowded, we can see that if any found themselves in drier conditions they might survive if they possessed or developed certain characters which protected them from becoming dried up. In that way the new conditions of life, on land, would select certain types of plants, for example such as had hard spores, and these would persist as land plants. Later, the protected position of the embryonic plant within the seed would be advantageous to land plants, and this condition would be selected and handed on to future generations.

I have mentioned only two characters, but there would be numerous others constantly arising, and if they were useful, plants possessing them would survive and hand on these characters until the new types of vegetation were widely different from those from which they had sprung. In this way we may conceive of natural selection as gradually causing a change in the character of vegetation, which all the time, as new characters were added, by variation, to the parental ones, became more and more complex. In some such way it is possible to imagine the gradual evolution of the higher types of plants from their more primitive ancestors.

This history of the gradual development in past

ages of the more and more complex types of vegetation we speak of as the evolution of plants. We must not, however, imagine that all the earlier types have disappeared and have been replaced by the more complex ones. For the plants described in the earlier chapters are plants living at the present day, which probably represent old types that have retained their primitive characters and are, like the seaweeds, for instance, still suited to aquatic conditions, in which we believe plants and animals, for that matter, first flourished. But we frequently find plants which tend to become extinct, either because the condition of their surroundings has so changed that they are no longer fit to survive, or more frequently because other and more vigorous types of vegetation tend to crowd them out. As plants of this kind which threaten to disappear, we may regard the Big or Mammoth Trees of California, which in spite of their size have not found it possible to hold their own except in some restricted groves in California, whereas formerly they had a much wider distribution. Similarly the maidenhair tree (see Chapter VIII), which was formerly found all over the northern hemisphere, would have disappeared almost completely had it not been cultivated around the temples in China. These are plants in process of extinction, while from fossil remains we know of many which have disappeared altogether from the existing flora.

So far we have been dealing with the past history of vegetation. What about the present and the

future? Are the same processes which caused the gradual evolution in the past still at work and will they cause changes in the future? One of the principal features of the Darwinian theory of evolution is that it tries to explain the past history of living organisms by factors which are controlling their life to-day. Variation and mutation, *i.e.* changes of certain characters among the numerous offspring of plants and animals, is an everyday observation of naturalists and horticulturists. The survival of the fit can be seen by anyone who cultivates plants, but the gradual change by natural selection of new and useful variations or mutations we cannot observe, as this would require countless generations of plants. On the other hand, if we wish ourselves to make such selections of forms which we desire to preserve, we can do so in a comparatively short time, and it is in this way that most of our cultivated plants and many of the new and beautiful varieties of flowers have been produced. This selection by horticulturists and plant breeders Darwin called "artificial selection," and it has proved most fruitful in the establishment of most of our agricultural crops and our garden plants. Now that we know more about the laws of inheritance, thanks to the work of the Abbot Mendel, we can by skilful selection and crossing of parent plants largely control the production of suitable offspring, which often inherit one desirable character from one parent and another from the other parental plant. Hybridisation allows us to combine many

useful or beautiful characters in the offspring, and "artificial selection" has become a purposeful process in the hands of the plant breeder. Natural selection can never be so definite, nor produce such rapid results.

CHAPTER XI

WHAT THE DISTRIBUTION OF PLANTS TEACHES US

If we find plants of the same kind or species growing in widely separated countries, we must assume either that the seeds of such plants have been carried great distances, if the plants do not occur in the regions between them, or that they have died out of such intermediate areas. Let us consider the first of the two alternatives. It often happens that islands arise in the oceans by volcanic action, by which the bottom of the sea becomes lifted up either above the water or near to the surface. In the latter case small coral-forming animals may build up coral reefs which come right up to the surface, and these may collect drifting wood and other debris so that finally a small atol or ring-shaped island is formed. It is then found that plants become established upon it, for the seeds and fruits of many tropical plants, by reason of the fact that they often contain air-chambers, float very readily. They also often retain their vitality though they may be immersed for a long time in sea-water. This is particularly the case with the cocoa-nut, the hard shells of which are surrounded by a thick fibrous covering around which is an impermeable

smooth coat. Cocoa-nuts are carried long distances by ocean currents, and when thrown up on the beach in tropical countries germinate readily in the sandy soil, if the temperature is sufficiently high, of bare islands which have arisen by volcanic action, and as in the case of many coral reefs, they will soon establish themselves. But there are other plants as well which can be dispersed by ocean currents. On the west coast of Ireland seeds from plants growing in the West Indies or along the Gulf of Mexico may be found thrown up. The seeds of a climbing plant, Entada, and the so-called "asses-eyes" (Mucuna) may be found on the Irish Coast, carried there by the Gulf Stream. They do not, however, germinate on Irish soil as the temperature is too low.

One of the best instances which shows how readily plants can be distributed to new and uninhabited islands is that of the colonisation by plants of the island of Krakatoa, in which the vegetation had been completely destroyed by a volcanic eruption. Ten years after the eruption the shore was covered with a fringe of trees and shrubs which had arisen from the seeds that had been carried there by ocean currents and thrown up by stormy seas. Not only was the shore colonised by these plants which had sprung up from water-borne seeds, but the bare rocks consisting of lava and pumice-stone began to show a vegetation which had developed out of wind-borne seeds and spores. Lichens first covered the rocks followed by mosses and liverworts, then by ferns and

flowering plants very much in the same order as plants had been evolved in former ages. It is in the case of such islands bare of vegetation that we can best study the way in which plants are distributed over wide regions of sea or land. Where many plants already exist it is more difficult to say whether certain plants which have their homes far away have been carried from a distance or whether they formerly occurred near-by and have since died out leaving some as it were stranded in outlying parts. Let us examine a case of one of these relicts, as they may be called. We may take the Common Rhododendron as an example. It is found in Portugal but nowhere else along the Mediterranean. We find it again along the coast of the Black Sea, and since it belongs to a group of plants which have their main seat of distribution in the Himalayan mountains, we may take it to be a plant of Eastern origin. How is it that we find it occurring so far from its Eastern home? Since we cannot imagine that its seeds have been carried all the way to Portugal without some having been left in various other countries around the Mediterranean, we must assume that at one time this Rhododendron grew in many intermediate regions, like Macedonia, Italy, and the South of France, but that it has since died out of these countries and for some reason has been able to go on growing in Portugal. If we compare the climate of Portugal with that of other parts of the Mediterranean region, we find there is a greater rainfall in Portugal than in

Spain, Italy, or Greece. This is no doubt owing to the fact that Portugal is nearer to the Atlantic and receives the rain-clouds that arrive with the western winds across the sea. Indeed we have evidence that the countries around the Mediterranean have a drier climate now than they had formerly, so that many plants which required a higher rainfall have now disappeared. This we know from an examination of some of the fossil plants which are found in Mediterranean countries. We have other instances of similar peculiar distribution of plants. On the Atlas Mountains in North Africa we find a tree called the Western Cedar, which is closely allied to the Cedar of Lebanon growing in Palestine. No other cedars occur along the north coast of Africa, which is now mainly desert or semi-desert, and has not a sufficient rainfall to enable even the dry-loving conifers to grow. The seeds of the cedar could not have been carried all the distance to the Atlas Mountains by the wind for they are much too heavy. We must therefore consider that at one time when North Africa was less of a desert region the cedars may have grown all along the coast of Africa, but that they have since disappeared, except on the Atlas Mountains, where the rainfall is greater, because these mountains, like the west coast of Portugal, catch the rain-clouds blowing over from the Atlantic. What we have learnt from the distribution of the Rhododendron of the northern countries of the Mediterranean is thus borne out by what the distribution of the cedar teaches us.

But there is this difference that the Atlantic cedar, isolated from its home in the East, has become modified by the conditions of the West and is no longer exactly like the Cedar of Lebanon. It has become a different variety. I said just now that the home of the cedar was in the East, and we know this to be the case, because the only other cedar is the Himalayan Cedar or Deodar, which is often cultivated in English gardens. These three cedars, all living on mountain chains, are isolated from each other by hundreds of miles of desert—the great Arabian desert between the Himalayas and the Lebanon and the Egyptian Desert and the Sahara between the Lebanon and the Atlas Mountains. Other facts concerning the distribution of the Mediterranean plants show us that not only was the climate moister in former times, but it was also warmer. In the Pyrenees we find a little rock plant, Ramondia, often grown in rock-gardens in England, which belongs to a family of plants almost confined to tropical and sub-tropical countries. Altogether the flora of the Mediterranean was originally probably like that of the south-east of Asia. The horse-chestnut for instance, which is a native of the Balkan Peninsula, has its nearest allies on the Himalayan mountains.

But it is not only the Mediterranean region which has become cooler. The whole of Europe has now a climate with a lower temperature than in former ages. The cycads and their allies, which I mentioned at the end of Chapter VIII, were in former times

distributed over the whole of the northern hemisphere. Now they are mainly found in the southern hemisphere, and in countries much hotter than Europe. Similarly the Araucarias, to which the so-called Monkey-puzzle belongs, are also largely distributed over the southern hemisphere. Both represent ancient types of plants, which have disappeared out of Europe, where only their fossil remains exist, probably owing to the climate becoming considerably colder, as it certainly was during the great Ice Age. Some other conifers which have also disappeared from Europe, as I mentioned in the chapter dealing with that group of plants, are the Swamp Cypress of the southern States of North America, and the Mammoth Trees of the Pacific Coast of America. Both of these two have disappeared owing to the change of temperature of Europe. But the fact that they occurred formerly in Europe and that a large number of other plants are even now common to Europe and America, separated as these continents are by the Atlantic, indicates that these continents must once have been more closely connected than they are at present. It has been suggested, therefore, that at one time there were wide land-bridges between the New and the Old World, over which plants and animals may have found their way, the former by gradual dispersal of their seeds. Such a land-bridge is thought to have run from Scotland over Iceland to Greenland, and thence to America. On the other hand, it has also

been suggested that at one time a northern circumpolar continent existed which connected the New and the Old World. As we know from fossil remains found in Spitzbergen and Greenland that these countries enjoyed a much warmer climate in former days, such a circumpolar continent could well account for the occurrence of similar plants on the now widely separated continents of Europe and Asia on the one hand and America on the other.

It is necessary to explain the occurrence of many similar plants in Africa and Central and South America respectively. It has been suggested, therefore, that these two regions were at one time connected by a large land-bridge, which has now disappeared in the Atlantic, and to which the name of " Atlantis " has been given. This is supposed to have stretched from Northern Africa to the West Indies. It is interesting to know that the " Atlantis " hypothesis is not a modern theory invented for explaining the distribution of plants and animals on the two sides of the Atlantic. In classical times, though the world was thought to stop in the westward direction at the Straits of Gibraltar, the so-called Pillars of Hercules, Plato speaks of a mythical island of Atlantis, which had been known to the ancient priests of Egypt, and which was supposed to have disappeared. This island was said to have been larger than Asia Minor and Lybia put together. This large island was supposed to have disappeared under the sea as a result of earthquakes and floods. If there is any truth in

this ancient belief, which was revived by the great traveller Humboldt, there might be a possibility of explaining many difficulties in the botanical distribution of plants. Geologists, however, do not seem to regard the existence of an "Atlantis" as very probable, as there is no indication from soundings taken in the Atlantic of any such sunk island or continent. A similar bridge farther south connecting South Africa with Brazil has also been suggested. This has been called "Arch-helenis." There seems, however, some doubt as to whether such land-bridges could have existed at a sufficiently late geological period to have been able to explain the distribution of recent plants.

The similarity between the flora of South Africa and that of Western Australia is extremely pronounced, and there are also distinct resemblances in the vegetation of Madagascar to that of India, so that the view has been put forward that a broad land-bridge existed across the Indian Ocean connecting Africa with Australia, and Madagascar with India. Such a double connection would really involve the existence of a continent in the place of the Indian Ocean, and to this hypothetical continent the name of "Lemuria" has been given. In past geological times there have been many cases of the sinking of land areas beneath the sea and subsequent uprising of land, of which we have clear geological evidence. Many rocks now forming even mountain chains contain unmistakable remains of marine animals,

that there can be no doubt that the land on which such geological strata are found was once at the bottom of the sea, and have since been raised up into continental areas. There is, therefore, no inherent impossibility in supposing that a now sunk "Atlantis" existed as a continent in times past, or that Western Australia and South Africa were connected to a now-vanished "Lemuria." We have, however, no direct geological evidence of these continents, and the beds of the Atlantic and the Indian Ocean give no indication of their existence.

A new view has, therefore, been put forward more recently which helps to account for some of the remarkable facts observed in the distribution of plants, and I may add also of animals, for the distribution of the latter also indicates a former connection of Europe and America and of Africa and Australia by land-bridges, or in some other way. The other way is that suggested by Wegener. According to Wegener's hypothesis, the land-masses which now form five continents, separated by wide expanses of the oceans, were at one time all joined together to form a single continent. It formed a solid mass floating on a semi-solid substratum, and at various periods by sudden changes of the deeper crusts of the earth the land-mass broke up into smaller pieces which gradually drifted apart, somewhat in the way a large sheet of ice floating on water might break into pieces, which would float away. Of course the drift would be slower as the substratum in which

the continents were embedded was not liquid but semi-liquid, and the movement of the solid land masses would be very gradual. According to this theory of Wegener the continents are considered to be still drifting away from one another, but so slowly that within historic times only very slight changes can be observed. Wegener brings forward many facts in support of his view. He points out, for instance, that if America were brought nearer to the Old World, it would be found that the Eastern portion of South America, south of the mouth of the Amazon, would fit very exactly into the Bay of Guinea in Africa. And not only would it fit to shape, but the geological nature of the rocks of these two continents shows a clear correspondence in structure. In the north, too, the geological formations of Scotland agree very closely with those of Newfoundland and Labrador, very much as they should do if these countries had been torn asunder. There are many other geological features which can be explained by such an assumption of a gradual separation of the existing continents from a more or less continuous land-mass. From the point of view of the geographical distribution of plants this theory is particularly helpful, for it would explain such facts as the identity of the past floras of the Old and the New World, and the existence of many of the same plants and of still more similar or nearly related species on either side of the Atlantic, and this without having to assume the existence in the past of the imaginary

continent "Atlantis." Similarly, as according to Wegener's theory Australia broke away at some time from Africa, it would have carried with it on its Western border some of the vegetation which is common to it and to South Africa.

Like all new theories, that of Wegener has met with much opposition, and partly on the ground that we have no satisfactory explanation as to why the primitive land-mass should split up and as to whether the underlying mass of semi-liquid substratum would allow of the movement—that is, the drifting apart of the continents. However, it has recently been shown that the radio-activity of the rocks may be considered to liberate sufficient energy so as to be able from time to time, but of course at very considerable intervals, to render the mass in which the continents are sunk more or less molten or fluid and so allow the continental masses to shift their positions. Evidence seems to be, therefore, accumulating that this newer view is likely to be correct, and that the change of continents has been a gradual and long-standing one, so that we can speak not only of the evolution of plants, but also of the evolution of the continents on which they are found growing.

CHAPTER XII

THE HISTORY OF THE BRITISH FLORA

In dealing with the Mediterranean Flora in the last chapter, I mentioned that it had undergone certain changes owing to the climate becoming cooler, and I also instanced the disappearance from the more northern parts of Europe of certain conifers, like the Swamp Cypress and the Big Trees (Sequoias), which are now only found in the warmer regions of the United States, Florida, and California respectively. Their disappearance from Europe must be put down to the climate becoming colder, and this change of climate in Europe, no doubt a very gradual one, came to a head in a series of arctic periods which make up the great Ice Age. During the greater part of these periods most of Europe including Britain was covered with enormous glaciers, the remains of which in the form of their moraines are still to be seen in many of the valleys of the Lake District for example. What was the cause of this change of climate and what caused the subsequent disappearance of the arctic conditions has not been definitely established. Some scientists like Wegener consider that there may have been an actual displacement of the Poles.

At any rate, it is proved by the remains of fossil plants that at one time the vegetation of Greenland and Spitzbergen was of a semi-tropical nature, and that can hardly have been the case if the North Pole occupied its present position. The long Glacial Period of Northern Europe killed off most of the previously existing plants in Britain, and though the southern counties of England do not show signs of having been covered with ice, there is no doubt that most of the plants now found in these countries would not have been able to grow so close to the ice-covered parts of Britain, and must have arrived there subsequently. Probably only arctic and alpine plants such as we find in Greenland now could exist there. Such plants may also have existed on the summits of some of the mountains, for though the valleys were filled with great glaciers, some of the steep, rocky peaks may have been bare of snow during the summer months, as they are in Switzerland today, but the more rounded and the higher hills were probably permanently snow-capped. When the climate became milder, however, and more hilltops became free for plants to gain a foothold on them, these would be of a kind we call arctic and alpine plants. Some of these are still to be found on our mountains and more particularly in Scotland. Their distribution and the fact that they are more numerous in Scotland than farther south seems to indicate that many of them have come across from Scandinavia, and they are often spoken of as the Scandinavian

elements of our flora. Some of them are, of course, similar to those of the Swiss Alps, but these also may have received them from Scandinavia. One of the typical Scandinavian plants is a little Primula, allied to the so-called Dusty-miller. It is called *Primula Scotica* and it occurs in Sutherlandshire and in the Shetlands. It is also found in Norway, but not in Switzerland, so that it is probably of Scandinavian origin. Another plant of similar origin is the Cloudberry, which grows plentifully on the Pennine Hills at an altitude of about 2000 feet, often covering large stretches of moorland. It belongs to the genus Rubus, to which the blackberry and the raspberry belong. Being of arctic nature it does not produce a tall stem but has a well-protected underground stem from which the short flowering shoots grow upwards, bearing a pair of leaves and a white star-shaped flower. The fruit when ripe is orange or red in colour, and is eaten by the grouse on the moors. In Norway it is called Multebaer, and is stewed and eaten or made into jam. In the autumn the leaves in dying away become beautifully bronze-coloured.

These are only two of the many Scandinavian plants in the British Flora. The little Dwarf Birch so typical of the moors and bogs, the so-called tundras, of Arctic Europe and Asia, is not uncommon in the Highlands of Scotland. The small Snow Gentian, not uncommon in the Alps as well as in the extreme north, is found on a few of the Scotch hills. The Dwarf or Moss Campion, a beautiful little mountain

plant forming dense, moss-like tufts or cushions covered, when flowering, with pink, star-like flowers, which is found in the Alps and on the mountains of Northern and Arctic Europe, is abundant in Scotland and extends more sparingly to the hills of the Lake District and Wales. Similarly the Alpine Lychnis, allied to our Ragged Robin, which grows in rocky situations in high altitudes or at great elevations in Northern Europe and Asia, is found on the summit of one mountain in Scotland and one in Cumberland

It is probable that towards the end of the Ice Age, when the glaciers were beginning to shrink, many of these arctic plants grew also at lower levels, just as they are found now near the sea-level in far-away Greenland, where only the low-lying ground is free from snow in summer. Some indeed are found surviving even at the present time at lower levels and in places which cannot now be considered either arctic or alpine from the point of view of climate. Thus the White Dryas which is common in the Arctic regions of Europe, Asia, and North America, though particularly abundant in Scotland, is not uncommon in limestone districts in the north of England and Western Ireland, which has a comparatively mild climate.

But though this Dryas and another alpine plant, the Spring Gentian, are found in the west of Ireland, this region is particularly remarkable for a number of Mediterranean plants which are found there, and there only, as far as their occurrence in the British

Isles is concerned. Some botanists have thought that they represent the remaining plants of that warmer climate, which, as I have said, has passed away on the approach of the Glacial Period. But since it seems now established that during the Ice Age the whole of Ireland was covered by ice, it is more likely that they are immigrant plants which have arrived since that arctic period. Moreover, it is noticeable that with one exception these Mediterranean plants have all got very light seeds which could easily be carried by the wind over great distances of sea or land. The one exception is the Arbutus or Strawberry tree, which, as the name indicates, has a soft berry about the size and appearance of a strawberry. This fruit is no doubt eaten by birds, and they may very well have carried the seed to the west of Ireland. From the fact that the seeds, whether carried by wind or birds do not seem to have been brought to Cornwall or Devonshire where they will readily germinate, it is thought that they have been brought over the Bay of Biscay to Ireland. They have, therefore, been called Iberian, that is Spanish as well as Mediterranean plants. They do not occur in Northern France, so much nearer to our shores, for the climate there is too cold for them. The Strawberry Tree or Arbutus is found all over the Mediterranean region, forming one of the features of the scrub vegetation known as maquis. It is only in Portugal and the west of Ireland, where the rainfall is high owing to the nearness of these countries to

the Atlantic, that the plant grows into a handsome tree. It has shiny evergreen leaves and white bell-shaped flowers, from which you can tell at once that it belongs to the Heath family. Two other members of this family growing in the west of Ireland have a similar Mediterranean origin. One is the white-flowered Mediterranean Heath, and the other St Dabeoc's Heath with large purple bells. Both are common on the boggy moorlands of Connemara. Other immigrants from the South include the so-called London Pride commonly cultivated in our gardens, though few people seem to know its southern origin.

Besides these plants from what we may call the far South, there have been more numerous immigrants since the Ice Age from the nearer South, namely, the north of France. These French or Gallic types are, of course, found more particularly in the south of England, some being limited to the south coast. Among these is the feathery shrub Tamarisk, often grown in seaside gardens, not only in the south of England, but also as far north as Southport. The Cornish Heath is another of the Gallic arrivals on our coast, being widespread on the opposite coast of Brittany. It is a handsome shrub with flowers resembling those of the bell-heather, but rather more pink than purple in colour.

Some of the Gallic immigrants, particularly those from north-eastern France, are more or less limited to the Chalk Downs, and therefore found especially in Kent, Sussex, and Hampshire, and not found in

Devon and Cornwall, where the rocks are of volcanic origin. In the distribution of plants, both in this and in other countries, we find that some plants are peculiar to limestone regions, while others seem to avoid limestone. The Heath family seems to dislike limestone and enjoys acid soils, like those of moorlands. On chalk and limestone the soil is either neutral or alkaline, and this suits some plants better than an acid soil, on which consequently they are not found. Among these chalk-loving plants which have been carried across from France is the Travellers' Joy (Clematis), which one sees so commonly along the chalk hills in France and which is almost equally common on the South Downs of England. The beautiful plumed seeds of this plant are eminently suited to be carried long distances by the wind. The evergreen Box is a common shrub in chalky regions, actually giving its name to Box Hill in Surrey. A number of orchids too which enrich the flora of the Downs may also be considered as immigrants from France. Orchids being the smallest seeded of Flowering Plants are very readily carried considerable distances, and could easily cross the Channel.

By far the greatest number of our Flowering Plants, however, have come from the East, *i.e.* Central Europe, and may consequently be called Germanic types. These make up three-quarters of our flora, and most of our common plants like daisies and dandelions belong to these. Their seeds have been

transported over the North Sea, and after gaining a footing on the east coast have made their way westward, occupying as time went on more and more territory. Some never got as far as Ireland, being stopped by the Irish Sea. This is the case with the Greater Meadow Rue. The Pasque Flower with its beautiful purple bells covered with silken hairs is found in England, but has stopped short in its journey and is not found in Wales, Scotland, or Ireland. Some of these Germanic types never got farther than the eastern counties of England. Thus the Crested Cow-wheat is limited to Eastern England, and so is the true Oxlip, so common in the woods near Cambridge.

While the Germanic types are the most numerous constituents of our flora, the least numerous and probably the most recent arrivals are a few American plants which are limited to the west of Ireland, the Hebrides, and the Isle of Skye. One of these plants is a little aquatic plant, the so-called Pipewort, growing in ditches on the moorlands of the western islands. It is entirely unknown on the European continent, but common in America, and its seeds have probably been carried across the Atlantic by sea-birds. A small Orchid belonging to the genus known as Lady's Tresses, also unknown in Europe and a native of North America, is found in meadows at Bantry Bay in Ireland; and the Blue-eyed Bermuda Grass with beautiful blue flowers and grasslike leaves, common in moist meadows throughout North

America, is found near Kerry and Galway and nowhere else in Europe.

Thus, you see, most of our plants are immigrants, a few of the arctic ones having possibly arrived during the Ice Age, but the majority when the land became gradually uncovered and the climate of Britain became milder. In this connection it is interesting to note that there is a greater proportion of small-seeded plants in the British flora than in that of Europe generally.

It is interesting, too, to compare the constitution of our flora with that of the population of Britain, which is similarly made up of a series of immigrants from the neighbouring countries. We may compare the Mediterranean types of plants to the ancient Celtic races, of which one branch, at all events, is found in Ireland, while it is quite possible that there may be descendants from Spaniards of the great Armada in Ireland too. The Scandinavian types of plants have their counterpart in the Norsemen and Danes who invaded Britain and left many traces in place-names in the north of England. The Gallic plants can be likened to the Normans who form a constituent of our population, and have enriched our language with many words of French origin. The Germanic invasion of plants we may compare with the arrival of the Angles and Saxons, who make up probably the greater part of our population just as the Germanic plants constitute the bulk of our flora. Lastly, have we not a few Americans settled in our

midst, returning to the home of their ancestors? They have their counterpart in the small number of more recently arrived American plants found in Western Ireland and Scotland.

Thus it will be seen the flora of Britain has developed, very much as our population has been formed, by numerous invasions from near and far, and it is as interesting to trace the gradual development of the British Flora as it is to study the early history of its people, and we find that a comparison of the two shows some very striking agreements.

INDEX

Acetic acid, 40.
" Acquired characters," 108.
Alcohol, 41.
Alpine Club-moss, 73.
Alpine Lychnis, 127.
" Alternation of generations," 65.
American Redwood, 87.
Angiosperms, 90.
Annual rings, 87
Antheridia, 50, 63, 72.
Antiseptic treatment, 39.
Ants, 98.
Araucarias, 118.
Arbutus, 128.
Archegonia, 50, 63, 72.
" Artificial selection," 111.
" Atlantis," 119.

Bacteria, 33.
Big Trees, 87.
Bishop's Pine, 84.
Bladder-wrack, 16.
Blue-green Algæ, 43.
Blue Mould, 27.
Bog-moss, 53.
Box, 130.
Bracken, 58.
Breathing roots, 86.
Brewers' yeast, 40.
Brown seaweeds, 13.

Calamites, 76.
Carboniferous plants, 65, 76.
Carrageen, 19.
Cedar of Lebanon, 116.
Chlamydomonas, 4.
Chlorophyll, 10.
Cilia, 5.
Cloud-berry, 126.
Club-mosses, 73.
Cluster Pine, 82.
Coal-measures, 76.
Colonisation by plants, 114.
Common Polypody, 56.
Conifers, 79.
Coralline seaweeds, 13.
Crested Cow-wheat, 131.
Cross-pollination, 95.
Cycads, 89.

" Damping off," 30.
Darwin, 108.
Deodar, 117.
Devonian plants, 103.
Diatomite, 9.
Diatoms, 7.
Dispersal of seeds, 98.
Drifting of continents, 121.
" Dry rot," 27.
Dwarf Birch, 126.

Elaters, 48, 71.
Epiphytes, 56, 75.
Euglena, 1.
Eye-spot, 3, 5.

Fairy rings, 25.
Fermentative changes, 40.

Ferns, 56.
Filmy ferns, 59.
Flagellum, 3.
Fossil ferns, 65.

Germs, 38.
Ginger-beer, 41.
Green Laver, 11.
Gymnosperms, 90.

Hair-moss, 50.
Harts-tongue, 57.
Honey guides, 93.
Horsetail, 67.
Hybridisation, 111.

Ice Age, 118.
Indusium, 61.
Irish Moss, 19.

Juniper, 85.

Kelp, 19.
Kieselguhr, 9.
Krakatoa, 114.

Lactic acid, 39.
Lamarck, 108.
Land-bridge, 118.
Larch, 80.
Laver, 19.
" Lemuria," 120.
Lepidodendra, 76.
Life-cycle, 64.
Liverworts, 44.
London Pride, 129.
Luminous fungi, 26.

Maidenhair Tree, 88, 110.
Mammoth Tree, 87, 110.
Marchantia, 45.
Mediterranean Heath, 129.
Mendel, 111.
Mesozoic plants, 105.
Moss Campion, 126.
Mosses, 49.
" Mummy wheat," 96.
Mushroom, 21.
Mutation, 111.

" Natural selection," 109.
Nitrifying bacteria, 37.

Origin of Species, 108.
Oxlip, 131.
Oyster Green, 11.

Parasites, 30.
Pasque flower, 131.
Peat, 54.
Pellia, 45.
Pipewort, 131.
Pleurococcus, 7.
Pollen, 93.
Prothallus, 62.
Protonema, 52.
Protoplasm, 10.
Protozoa, 3.
Puff-Ball, 25.

Quillwort, 77.

Ramondia, 117.
" Recapitulation theory," 53, 62.
Red seaweeds, 12.
" Red snow," 5.
Respiration, 69.
Rhododendron, 115.
Rock-pools, 12.
Root-tubercles, 37, 42.
Rust, 30.

St Dabeoc's Heath, 129.
Salmon disease, 30.

Saprophytes, 30.
Sargasso weed, 18.
Scots Pine, 80.
Scouring Rush, 69.
Sea-Lettuce, 11.
Seed-bearing ferns, 66.
Seed-vessel, 90, 96, 98.
Self-pollination, 95.
Shield Fern, 60.
Silica, 7, 69.
Silver Fir, 82.
Smut, 30.
Souring of milk, 39.
Sphærella nivalis, 6.
Spore capsule, 48.
Spruce, 81.
Stagshorn Moss, 73.
Sterilisation, 39.
Survival of the fit, 108.
Swamp Cypress, 86.
Swamp forests, 86.
Symbiosis, 42.

Tangles, 14.
Tertiary coal, 86.
Thallus, 44.
Toadstool, 25.
Travellers' Joy, 130.
Turf-moss, 53.

Variation, 111.
Vinegar, 40.
Vitamines, 9.

Wart disease, 30.
Wegener's hypothesis, 121.
White Dryas, 127.
White or Pin Mould, 29.
Wort, 41.

Yew, 85.

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